



**Expert Report of
Brian L. Murphy, Ph.D.**

Prepared for Faegre & Benson, LLP



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Brian L. Murphy, Ph.D.**

**In the United States District Court
For the Northern District of Oklahoma**

STATE OF OKLAHOMA, *ex rel*, W.A. DREW EDMONDSON in his capacity as
ATTORNEY GENERAL OF THE STATE OF OKLAHOMA and OKLAHOMA
SECRETARY OF THE ENVIRONMENT

O. MILES TOLBERT, in his capacity as the TRUSTEE FOR NATURAL RESOURCES
FOR THE STATE OF OKLAHOMA,

Plaintiffs,

v.

TYSON FOODS, TYSON POULTRY, INC., TYSON CHICKEN INC.,
COBB-VANTRESS, INC., AVIGEN INC., CAL-MAINE FOODS, INC.,
CAL-MAINE FARMS, INC., CARGILL, INC., CARGILL TURKEY PRODUCTS, LLC
GEORGES, INC., GEORGES FARMS, INC., PETERSON FARMS, INC.,
SIMMONS FOODS, INC., AND WILLOWBROOK FOODS, INC.

Defendants

Case No. 05-CV-329-GKf-SAJ

Prepared for
Faegre & Benson, LLP

Prepared by

A handwritten signature in black ink that reads "Brian L. Murphy".

Brian Murphy, Ph.D.

Exponent

January 27, 2009

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Acronyms and Abbreviations

IRW	Illinois River Watershed
PC	principal component
PCA	principal components analysis
PVA	polytopic vector analysis
SPLP	synthetic precipitation leaching procedure
WWTP	wastewater treatment plant

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Executive Summary

I have been retained by Faegre & Benson, LLP, on behalf of Cargill, Inc., in the context of litigation over poultry litter application to fields in the Illinois River Basin. Specifically, I was asked to examine Dr. Roger Olsen's report, affidavit, deposition testimony, and related documents in this case, in order to determine: (a) whether the data set used by Dr. Olsen for the Cargill contract turkey growers was sufficient to support the implication that they are responsible for determinable downstream concentrations; (b) whether the statistical analysis performed by Dr. Olsen, known as principal components analysis, or PCA—which leads him to conclude that poultry growers generally are a determinable source of downstream chemical and bacterial concentrations—was conducted and interpreted in an appropriate manner; and (c) if the statistical analysis were conducted in an appropriate manner, whether it supports a conclusion that any Cargill contract grower or any other grower is responsible for determinable downstream concentrations.

PCA is often used in environmental studies to determine which samples are similar—that is, appear to originate from a common source—and which samples are different, when the number of samples and the number of analytes (chemicals, bacteria, etc.) in each sample is too large to determine such relationships simply by inspecting the data. The output of PCA consists of a multidimensional loadings plot and a multidimensional scores plot. Analytes that occupy the same area of a loadings plot co-vary; that is, the concentration goes up and down in tandem from sample to sample. Samples that may represent different locations and media (soil, water, etc.) can occupy the same area of a scores plot, thus behaving as if they have a common source.

My principal conclusions are as follows:

- **Cargill contract grower data used by Dr. Olsen in his PCA are either too limited to draw conclusions or lead to conclusions that are opposite those drawn by Dr. Olsen.**
 - There are 35 Cargill contract growers in the Illinois River Basin. Dr. Olsen collected data at just two contract growers. At one Cargill contract grower, he collected only one turkey-litter sample and no environmental samples.
 - At the other contract grower location, Mr. Schwabe's farm, Dr. Olsen collected turkey-litter and some environmental samples, including two spring samples, a Geoprobe® groundwater sample, and soil samples at four locations. However, he did not use all of these data in his analyses. In part, this was because he was not able to detect a sufficient number of analytes—i.e., the samples were “too clean”—and in part for reasons that he fails to explain.
 - Dr. Olsen selected analytes that are commonly found in soil and elsewhere in the environment. He failed to select sufficient analytes that were specific to poultry litter or even to living organisms.

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- The data from the Schwabe farm that he did use do not support allegations of chemical and bacterial concentrations in the environment due to turkey litter. This is because of: (1) the consistency of soil samples with background reference samples, (2) the confounding presence of cattle at the two spring locations that were sampled, and (3) the sample at the spring he identified as unaffected by cattle, as well as the Geoprobe[®] groundwater sample, do not have the supposed poultry litter “signature” determined by his PCA.
- **Dr. Olsen’s interpretation of his PCA results is unconventional and improper.**
 - Dr. Olsen identifies principal components (PCs) with specific sources, which generally is not correct; because of mathematical constraints, PCs do not represent real entities such as source compositions. Other statistical methods have been developed, which Dr. Olsen did not use, where these constraints are removed and vectors or end members (similar to PCs) can represent real entities.
 - Dr. Olsen adds an arbitrary number to all his PC scores so that they are all positive. He then focuses on high adjusted scores as evidence of poultry litter-related effects. This approach overlooks important information regarding relationships between samples. In PCA, negative scores are just as important for interpretation as positive scores, and it is not unusual to have negative scores whose magnitude is as large as the positive scores.
 - Only samples with similar scores on more than one PC behave as if they have a common source. By examining PC loadings individually and not collectively, Dr. Olsen overlooks important relationships between analytes. Dr. Olsen presents information for the loadings on PC1 separately from loadings on PC2, PC3, etc. This obscures the actual relationship between analytes. Examining loadings for PC1 alone, he concludes that the largest loadings must have a common source. However, when loadings from multiple PCs are looked at in a multidimensional space, different relationships appear. In particular, analytes commonly found in soil have similar loadings on multiple PCs. Further, the wide variability in PC2 loadings indicates that the analytes with the largest PC1 loadings do not have a common source. In particular, some analytes vary inversely on PC2 to others; that is, one goes up when the other goes down.
 - Dr. Olsen attributes large loadings to analytes with high concentrations. However, loadings are not concentrations; in particular, large loadings do not represent large concentrations. Loadings determine the contribution of each analyte to a PC, and PCs explain the maximum variability between samples. Because the emphasis is on describing variability, and not on concentration, adjusted concentration data are used as input to the PCA. As part of the adjustment, the average across samples is subtracted from each sample concentration (or the logarithm of each concentration), and the result is divided by the standard deviation across samples. Because the standard deviation is a measure of the variability or range of the data, the adjusted

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concentrations of different analytes are more similar than the measured concentrations. That is, concentrations in the 100s are likely to be divided by a standard deviation comparable to 100, while concentrations in the 10s are likely to be divided by a standard deviation comparable to 10.

- **Dr. Olsen made a fundamental mathematical error which renders all of his results invalid.**
 - In brief, Dr. Olsen used a log-transformed dataset to derive the PC coefficients, but calculated the PC scores based on a dataset that was not log-transformed.
- **Dr. Olsen's PCA is not a true "pathway" analysis, because he does not combine solid and liquid samples in the same analysis. A multimedia analysis indicates that Cargill contract growers, including the sole Cargill contract grower with onsite environmental data, are not contributing determinable downstream concentrations.**
 - A multimedia PCA demonstrates that Dr. Olsen's allegation of a unique chemical signature along an environmental pathway is incorrect; instead, the "signature," as defined by the PCA scores plot, changes continuously along the pathway from medium to medium.
 - Soil samples from the Schwabe farm are indistinguishable from reference, supposedly background, soil. Sediments downstream of Cargill contract grower facilities appear to be composed of native soils.
 - Some edge-of-field samples appear to be dominated by native soils. Dr. Olsen did not collect edge-of-field samples from any Cargill contract grower farm.
 - Edge-of-field samples from pastures with cattle and no poultry litter are indistinguishable from edge-of-field samples where poultry litter has been applied and cattle may be present. Furthermore, to the extent edge-of-field samples overlap with samples impacted by cattle manure or poultry litter, the edge-of-field samples are more similar to the synthetic precipitation leachate procedure (SPLP) samples from cattle manure than SPLP samples derived from poultry litter.
 - Surface-water samples, including those downstream of Cargill contract grower facilities, and wastewater treatment plant (WWTP) samples, are similar in composition (i.e., tightly clustered in the PCA) and are very different from poultry-litter samples at Cargill contract grower and other poultry facilities. Some groundwater and spring samples, including those associated with the Schwabe farm, lie outside this cluster yet still are distinct from the poultry-litter samples.

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1 Introduction

I have been retained by Faegre & Benson, LLP, on behalf of Cargill, to provide opinions in this case.

I was asked to examine the following issues related to the report prepared by Dr. Roger Olsen for the State of Oklahoma:

- What Cargill contract grower¹-specific data did Dr. Olsen use? Are these data sufficient to support Dr. Olsen's implied claim that Cargill's contract grower turkey litter is making a detectable contribution to the chemical and bacterial content of downstream water bodies?
- Is Dr. Olsen's use of principal component analysis (PCA) appropriate, and does it support his claim that poultry litter is making a contribution to the chemical and bacterial content of downstream water bodies that is detectable by the PCA:
 - For the Cargill contract growers?
 - For other poultry growers?
- Does an appropriate use of PCA indicate detectable downstream concentrations:
 - Attributable to the Cargill contract growers?
 - Attributable to other poultry growers?

1.1 Qualifications

Since July 1, 2002, I have been a Principal Scientist at Exponent, Inc., an engineering and science consulting firm. I received Ph.D. and M.S. degrees in 1966 and 1963 from Yale University and a Sc.B. from Brown University in 1961.

From 1965 to 1975, I was employed by Mt. Auburn Research Associates, a Department of Defense consulting firm. From 1975 to 1985, I held several positions at ENSR (formerly Environmental Research and Technology), including Chief Scientist in Environmental Operations and Research, Manager in the Air Quality Studies Division, and General Manager in the Policy, Planning, and Earth Resources Center. I was the founding President of Gradient Corporation, an environmental and risk assessment consulting firm, in 1985, and remained with that firm until it was purchased by the engineering firm IT Corporation, in 1995.

¹ There are 29 Cargill contract growers and 6 Cargill breeder operations in the Illinois River Watershed. For brevity, I refer collectively to these as "Cargill contract growers."

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I remained at IT Corporation until 1999 and then joined Sciences International, another environmental and risk assessment consulting firm, as a Vice-President. In 2002, I was a self-employed environmental consultant. I have also been a Visiting Instructor at the Harvard School of Public Health and the University of South Florida.

My consulting practice focuses on mathematical modeling, applications of environmental forensics techniques, and dose reconstruction. I have more than 30 years of experience in data analysis and mathematical modeling of pollutant fate and transport in various media and am the author of more than 30 journal publications, as well as numerous technical reports and presentations. I am also co-editor of the Academic Press texts *Introduction to Environmental Forensics* and *Environmental Forensics: Contaminant Specific Guide*, and am on the editorial board of the journal *Environmental Forensics*. I am also coauthor of the book *Controlling Volatile Emissions at Hazardous Waste Sites*, published by Noyes Data Corporation of New Jersey.

In conducting this investigation, I reviewed Dr. Olsen's July 25, 2008 report, as well as his October 26, 2007 affidavit and supporting material produced on December 4, 2007; January 3, 2008; and January 22, 2008. I also had access to data and reports generated by other plaintiffs' consultants. I have also consulted PCA studies conducted by others, to see whether Dr. Olsen's use of PCA is customary. My opinions are based on my review of these documents, as well as my scientific training and experience, and my review of environmental data for the Site.

A copy of my *curriculum vitae* is included as Attachment A, and a list of the documents I have reviewed is included as Attachment B.

1.2 Compensation

Exponent is being compensated for my time at my usual rate of \$350 per hour.

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2 Background

In the Illinois River Watershed (IRW), both chicken and turkey litter is spread on fields as fertilizer for pasture land. Beef cattle and some dairy cattle are raised in the watershed.

Cargill has 35 contract turkey-growing facilities in the IRW. As discussed in the next section, Dr. Olsen used virtually no onsite data from the Cargill contract growers in the IRW.

Following precipitation events, water can run off fields. Precipitation also percolates through the soil and may recharge groundwater. Exchanges of water occur between surface water and groundwater. These exchanges manifest in the form of springs and both gaining and losing streams.

The basic question is whether or not the chemicals and bacteria found in poultry litter are released to the environment through precipitation in sufficient concentrations, and then subsequently are transported with insufficient dilution or loss, so that identifiable concentrations exist downstream in recreation or other areas in any amount significant enough to cause harm.

One way to address that question is to try to identify a poultry litter “signature” that persists from the poultry litter to edge-of-field, to groundwater, to springs, and to surface water. This is the approach that Dr. Olsen has taken using a statistical technique known as principal component analysis (PCA).

2.1 Principal Component Analysis

PCA is similar to the children’s game of “one of these things is not like the others.” In our case, the things that we want to determine whether they are alike or not are environmental samples. We have hundreds of samples of water, soil, and other media that have been analyzed for many different chemicals, bacteria, or other properties (referred to collectively as analytes, or variables). Determining which samples are similar, or different, becomes difficult to impossible by simply reading the sample results because of the large number of samples and analytes. PCA is one of a number of statistical methods known as “multivariate,” designed to objectively analyze data when the number of variables (or analytes) and/or samples is large. To be valid and useful, a PCA must be based on appropriate variables, must be conducted correctly, and must be interpreted in an appropriate manner. As described below, Dr. Olsen has not done any of these things.

To illustrate the concept of PCA, start by considering one sample, A, with results for three analytes, X, Y, and Z. A principal component (PC) is described as:

$$PC1 = aX + bY + cZ$$

where the “1” indicates that this is the first PC, and a, b, and c are numbers known as “coefficients” for each analyte for that component. It is as if we have defined a new variable made up of a combination of the original analytes. Each sample has its own value for each PC

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based on the specific sample data for X, Y, and Z, and the specific a, b, and c values for that component. These values are known as “scores” for each PC. These coefficient values depend on the scale of the input data (i.e., X, Y, etc.); thus, “loadings” are rescaled coefficients that represent the correlation between an analyte and a PC.

In this case, X, Y, and Z are not the actual measured concentrations, but are adjusted concentrations. Adjusted concentrations are used as input, because the focus of the analysis is on the composition of samples rather than the magnitude of concentrations. There are many commonly used adjustment methods. Dr. Olsen subtracts the average concentration from each sample concentration (or the logarithm of the sample concentration), and divides the result by the standard deviation. Because the standard deviation is a measure of the variability, or range, of the data, the adjusted concentrations of different analytes tend to be more similar in magnitude. That is, concentrations in the 100s are likely to be divided by a standard deviation value comparable to 100, while concentrations in the 10s are likely to be divided by a standard deviation value comparable to 10. In my use of PCA in Section 5, I adjusted concentrations by dividing each sample concentration by the sum of the analytes in the same chemical group (i.e., metals, bacteria, etc.). In this manner, each metal is expressed as the relative proportion of total metals included in analysis. Similarly, each bacterium is expressed as the relative proportion of the sum of bacteria variables included in the analysis.

The numbers a, b, and c are determined through some fairly complicated mathematics to best achieve PC1 scores for multiple samples that spread them as far apart as possible, so as to explain as much of the variability between samples as possible.

A second PC can be determined as:

$$PC2 = a'X + b'Y + c'Z$$

where a', b', and c' are the coefficients specific to PC2. These are determined similarly in a way that causes the PC2 scores for multiple samples to be spread apart as much as possible, thus ranging across the widest range of PC2 values.

PC2 is determined, again using fairly complicated mathematics, to be at right angles to PC1.²

Each sample has a specific location in the PC1-PC2 space based on its specific scores for PC1 and PC2, used as coordinates in the x-y plot of PC1 vs. PC2. We can then proceed to do this for all other samples: sample B, sample C, etc. This scatter plot is known as a “scores plot.” Samples whose scores are in the same area of the PC1-PC2 space are considered similar, because similar scores indicate similar composition. Similar composition suggests a common source. Because the PCA is based on adjusted data rather than measured concentrations, samples of similar composition that have been diluted to varying degrees still remain in the same area of the plot.

² PC3 would be at right angles to both PC1 and PC2. This is easy to visualize as the familiar x-axis, y-axis, z-axis coordinate system. More PCs than three can be determined, and mathematically, they are “at right angles” to the previous ones, but of course, this is difficult to visualize.

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We can also form what are known as “loadings plots.” Loadings are the rescaled coefficient values, such that each loading represents the correlation between an analyte and a PC. We then locate the first analyte in the PC1-PC2 space based on the loading of analyte X with the first PC, PC1, on the x-axis and the loading of analyte X with PC2 on the y-axis. Every analyte can be located based on its respective “loading” values for PC1 and PC2. If two analytes plot in the same area of the PC1-PC2 space (a and b are similar, and a’ and b’ are similar), then these analytes are said to “co-vary,” meaning that across samples, when one analyte goes up, the other also goes up, and the same with decreases. Similarly, when two analytes plot far apart (i.e., a and b are not similar, or a’ and b’ are not similar), the two analytes do not co-vary and thus are unlikely to come from a common source.

Several basic points follow from this discussion:

- PCs are not real entities, such as source “signatures.” They are purely mathematical entities formulated to describe the variability within sample data. Because they are not real entities, scores and loadings can be negative as well as positive.
- A large PC score does not mean high concentrations. Because adjusted data are used, PCA does not address the magnitude of concentrations; instead, it is based on relative concentrations. A sample with concentrations of 100, 200, and 300 will be determined to be the same (i.e., to have the same PC scores) as a sample with concentrations of 1, 2, and 3, assuming the same units, because their relative concentrations are the same.

2.2 Special Samples

A number of samples used in Dr. Olsen’s analyses are selected for a particular purpose. These are summarized in Table 2-1.

As Table 2-1 makes clear, Dr. Olsen’s analyses focus on poultry litter, cattle manure, and wastewater treatment plants (WWTPs). For example, he does not consider the effects of septic tanks, urban runoff, stream-bank erosion, hog farms and hog waste lagoons, wildlife, land application of sewage sludge, land irrigation by WWTP effluent, sanitary sewer overflows, or runoff from heavily fertilized areas such as nurseries, golf courses, and lawns.

As indicated in Table 2-1, it does not appear that Olsen’s reference samples represent true background or reference conditions; that is, unaffected by poultry litter but affected by other factors (such as WWTPs, urban runoff, septic tanks, etc.) to the same degree as other locations. Two edge-of-field samples were taken at the Fite farm (CP-1-A and CP-1-B). One is in standing or ponded water, and the other is up-field rather than edge-of-field.

The analytes chosen by Dr. Olsen for his PCA are mostly elements that are common in soils and groundwater, such as arsenic, aluminum, barium, calcium, chlorine as chloride, copper, iron, magnesium, nickel, potassium, sodium, and sulfur as sulfate. These analytes also include much double counting. For example, *e. coli*, *enterococci*, and fecal coliform all measure fecal coliforms, yet all three are included in the PCA; both total Kjeldahl nitrogen and nitrite+nitrate

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are included; and three measures of phosphorus are used. The net effect is to (a) potentially let native soils dominate the PCA, and (b) overweight the analytes that are multiply counted. Dr. Olsen did not use compounds such as sterols in his analysis. While not specific to poultry, use of such compounds instead of native soil elements would have helped address the possibility of mistaking a native soil signature for a poultry litter signature.

Table 2-1. Special-purpose samples used in Dr. Olsen's analyses

Type	Locations	Purpose	Comments
Reference Conditions			
Lake water	BBL-03, BBL-06, BBL-07, BBL-08	Believed by Olsen to be unaffected by poultry litter	31 million poultry head in Broken Bow Lake Watershed*
Stream water	BS-REF1, RS-10003, RS-10004, BS-REF2, BS-REF3	Believed by Olsen to be unaffected by poultry litter	5 poultry houses upstream of REF1*; 35 poultry houses in Spring Creek areas, many upstream of REF3*; Reference streams less affected by standard urban and other factors*; No high flow conditions sampled.
Lake sediment	BBL-03, BBL-06, BBL-07, BBL-08	Believed by Olsen to be unaffected by poultry litter	31 million poultry head in Broken Bow Lake Watershed*
Stream sediment	BS-REF1, BS-REF2, BS-REF3	Believed by Olsen to be unaffected by poultry litter	5 poultry houses upstream of REF1*; 35 poultry houses in Spring Creek areas, many upstream of REF3*
Soil	CL-1A, CL-1B, CL-2A, CL-2B, CL-3A, CL-3B	Believed by Olsen to be unaffected by poultry litter. All are surface soil samples.	
Wastewater Treatment Plant Effluent			
	Lincoln, Rogers, Siloam, Springdale	Characterize WWTP signature	
Cattle Impacts			
Cattle manure	MAN-BC-20D, MAN-BC-20F, MAN-BC-21D, MAN-BC-21F, MAN-BC-22D, MAN-BC-22F, MAN-BC-23D, MAN-BC-23F, MAN-BC-24D, MAN-BC-24F	Characterize cattle manure signature	
Edge-of-field from cattle pasture	EOF-CP-1A, EOF-CP-1B	Runoff from cattle pasture	Includes samples of ponded water and upslope runoff.
Cattle pasture soil	CP-1-A, CP-1-B, CP-2-A (Ed Fite and Jerry Hammonds farms)	Believed by Olsen to be unaffected by poultry litter and unaffected by commercial fertilizer for 7+ years. All are surface soil samples.	
Synthetic Precipitation Leachate Procedure			
Poultry litter	FAC-16, FAC-17, Litter5	Artificially produced leachate from poultry litter	

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Type	Locations	Purpose	Comments
Cattle manure	MAN-BC-20D, MAN-BC-20F, MAN-BC-21D, MAN-BC-21F, MAN-BC-22D, MAN-BC-22F, MAN-BC-23D, MAN-BC-23F, MAN-BC-24D, MAN-BC-24F	Artificially produced leachate from cattle manure	
Cattle pasture soil	CP-1-A, CP-1-B, CP-2-A	Artificially produced leachate from cattle pasture	
Synoptic Sampling	SN-SBC2	Differences between upstream and downstream of a point source, but only one sample was included in Olsen's analyses.	

Note: Additional synoptic samples collected at locations RS-780, SN-1LR-07, SN-BLDC1-03-4, SN-CAN, SN-MUD, SN-OSAGE, SN-R550, SN-RS-728, SN-RS776, SN-SBC, SN-SGR, and SN-SPRING.

* Comments from Dr. Olsen's September 10-11, 2008 deposition, made by others but uncontested by Dr. Olsen.

In spite of serious disagreement about the appropriateness of the analytes included in these analyses, this report proceeds with review of Dr. Olsen's PCA results using the same data he used. Similarly, in spite of reservations as to what some of the samples in Table 2.1 represent, in particular whether some of them really represent background conditions, this report refers to samples by the designations used by Dr. Olsen.

The remainder of this report focuses on Dr. Olsen's PCA runs SW3, SW17, SD1, and SD6, as well as my own analysis that combines all media. SW3 is a surface-water analysis. SW17 is based on the same samples as SW3, with the inclusion of groundwater. Neither analysis includes the synthetic precipitation leaching procedure (SPLP) samples. SD1 analyzes solids, excluding subsurface soil samples and sediment cores from Lake Tenkiller. SD6 is based on the same samples as SD1 plus the core samples from Lake Tenkiller and eight additional stream sediment samples.

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3 Plaintiff Sampling at Cargill Contract Growers' Locations

Sampling was conducted for only two Cargill contract turkey growers—Robert Schwabe and Clyde Masters.

At Masters' location, poultry litter was sampled by plaintiffs at only one station (FAC-14). One poultry litter sample was also analyzed from Schwabe's farm (FAC-08). Also from Schwabe's farm, two groundwater samples (LAL-16-GW-1 and LAL-16-GW-2), two spring-water samples (LAL-16-SP1 and LAL-16-SP2), one Geoprobe[®] groundwater sample (GP-GW-10), and soil samples at four locations (LAL-16A, LAL-16B, LAL-16C, and LAL-16D) were collected. Soil samples were collected at the surface (0–2 inches) and subsurface (2–4 inches and 4–6 inches). Mehlich phosphorus was the only analyte measured in the 4- to 6-inch depth interval; 11 analytes were measured for the 0- to 2-inch depth at LAL-16A, and the 2- to 4-inch depth at LAL-16A, LAL-16C, and LAL-16D; and more than 34 analytes were measured for the 0- to 2-inch depth at LAL-16B, LAL-16C, and LAL-16D, and the 2- to 4-inch depth at LAL-16B.

Olsen's SD1 and SD6 analyses include only three of the soil samples from Cargill contract growers that had more than 34 analytes. All three are from the Schwabe farm, which covers approximately 592 acres, or nearly a square mile. Clearly, three samples are inadequate to characterize conditions across the entire Schwabe farm.

There are a number of subsurface soil samples that appear to have adequate data for inclusion in Olsen's solid materials runs (SD1 and SD6) but that were not used, including the fourth Schwabe sample with 34 analytes (2- to 4-inch depth at LAL-16B³). The reasons for exclusion are not discussed in Olsen's report. The other (non-Cargill-related) samples appear to have detected results for virtually all of the analytes included in Olsen's analyses; therefore, the presence of too many non-detect results does not seem to justify exclusion. These samples include LAL-2A-4, LAL-2A-6, LAL-3A-4, LAL-3A-6, LAL-3B-4, LAL-3B-6, LAL-10A-4, LAL-15B-4, LAL-15B-6, CL-1A at depth, CL-1B at depth, CL-2A at depth, and CL-2B at depth. The CL- samples are reference soil samples. Including them would have shed more light on the variability of background sample compositions.

In addition to samples being excluded without justification, there is some discrepancy in the identification for Cargill contract grower samples from location LAL-16B. Olsen's spreadsheet of results identifies sample "LAL-16B 7/17/2006:SL:S:2:-" as subsurface soil in a column labeled EDA_Group ("SD-Soil-Subsurface"). This also occurs for one other sample (LAL-5D:6/12/2006:SL:S2:-) in both his SD1 and SD6 analyses. Both samples have sample names that indicate they are from the 0- to 2-inch depth interval (sample names ending in 2) (i.e., not subsurface). By elimination of other possibilities, the sample from LAL-16B is probably a surface soil sample. The 2-to 4-inch sample taken at LAL-16B on 7/17/2006 had only 13

³ Other subsurface samples at LAL-16A, LAL-16C, and LAL-16D do not meet Olsen's selection criteria for PCA, because too few analytes were measured.

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analytes measured, and the 4- to 6-inch sample had only one analyte measured; thus, both were not suitable for inclusion in analyses. Interpreting this as a surface sample is consistent with Dr. Olsen's descriptions of his SD1 and SD6 analyses in his produced PCA_Solids_Runs_Table(2).xls file.

At neither the Schwabe nor the Masters locations were any edge-of-field samples collected. Thus, a critical link in Dr. Olsen's transport theory is missing.

As with soil samples, not all of the samples collected in other media were used in Olsen's water analyses that form the basis of his report (SW3, SW17). The only two groundwater samples associated with Schwabe's farm were excluded, because they had too few analytes detected to meet Olsen's inclusion criteria. This, in itself, indicates a lack of significant poultry litter-related concentrations. Except for the one Geoprobe® groundwater sample from Schwabe's nearly one-square-mile property, no groundwater samples from Cargill contract growers enter his analyses. Thus, the Cargill contract growers are inadequately characterized or not characterized at all, and a second critical link in Dr. Olsen's transport theory is missing.

Table 3-1 summarizes the samples from Cargill contract growers included in Olsen's analyses:

Table 3-1. Summary of samples from Cargill growers used in Dr. Olsen's analyses

Sample Type	Grower	
	Schwabe	Masters
Poultry Litter	FAC-08	FAC-14
Surface soil	LAL-16B, LAL-16C, LAL-16D	-
Edge of field	-	-
Groundwater(Geoprobe®)	GP-GW 10	-
Springs	LAL-16-SP1, LAL-16-SP2	-

3.1 Comparison of Cargill Contract Grower Samples to Other Samples

3.1.1 Cargill Contract Grower Solid Samples

Olsen provides plots of his solid sample analyses, including poultry litter and soil, in his Figures 6.11-20c (run SD1, PC1 vs. PC2), 6.11-20e (run SD1, PC2 vs. PC3), and 6.11-21c (run SD6, PC1 vs. PC2). These figures are reproduced in this report, with the Schwabe and Masters samples and locations downstream or downgradient of Cargill contract growers identified, as

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Figures 3-1, 3-2, and 3-3. Reference (background) sample locations have also been identified. These figures show the Varimax rotation results for SD1 and the non-rotated results for SD6, because these are the results that Olsen relies upon. They reflect Olsen's unconventional procedure of adjusting PC scores by adding a constant, so that no negative scores occur and the smallest positive score is +1.

Clearly, the Cargill contract grower poultry litter samples, as well as all other poultry litter samples, have a different principal component composition from the other samples included in Olsen's analyses, particularly for the first two PCs (Figures 3-1 and 3-3). This means that no "poultry litter signature" is seen in the environmental or other samples. The other fact worthy of note is how closely the Cargill contract grower soil samples resemble the reference soil samples. The latter are samples that CDM believed to be unaffected by both poultry litter and cattle manure. In Figure 3-1, the Cargill contract grower samples and the reference samples are indistinguishable for the first two PCs. Even with the addition of a third PC in Figure 3-2, two of the three Cargill contract grower soil samples are indistinguishable from the reference soil samples. Similarly, in Figure 3-3 for his SD6 analysis, the Cargill contract grower soil samples are near the reference soil, and the sample from LAL-16B is indistinguishable from reference soil samples.

3.1.2 Cargill Contract Grower Spring-Water Samples

The spring samples associated with Schwabe's farm are located within subbasin 24. According to Apex, both springs are about 1½ miles upgradient from the poultry houses. Other sample locations included in Olsen's water PCA runs (SW3 and SW17) that are downstream of Cargill contract growers are from other subbasins; specifically, three samples from subbasin 6 and one sample from each of subbasins 4, 7, 14, and 15.

In his report, Olsen identifies one of the spring samples (LAL-16-SP2) as having been affected by cattle. The CDM field notebook states, "many cows in area and in spring channel." This is consistent with the Apex report for this location, which noted that there were about 70 head of cattle present north of the spring when the site was visited and photographed on July 7, 2008. Apex also noted that there was a cattle feeder facility north of the spring and that cattle had access to the area where the spring sample was taken. Furthermore, they noted that the spring and stream locations were in a low area and received runoff from the surrounding hills. In Olsen's Figure 6.11-25, LAL-16-SP2 is the sample with the highest PC2 score and clearly has a different composition from the other samples in that figure.

Olsen's report does not identify the other spring sample (LAL-16-SP1) as being affected by cattle. However, the CDM field notebook states "cows in area." Furthermore, when Apex visited this location, also on July 7, 2008, they noted about 100 head of cattle and cattle manure south of the spring sample location. Apex further noted that there was a mineral feeder for cattle about 20 feet from the stream, and that cattle had access to the stream and spring. The LAL-16-SP1 sample location is in a low-lying ravine that is also subject to runoff from the surrounding terrain.

In any case, based on the PCA loadings from SW3 and SW17, sample LAL-16-SP1 does not resemble Olsen's poultry signature, because many of the important analytes were not detected.

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Review of the analytes with large positive loadings for PC1 from his SW3 run shows that four of the top six most heavily weighted were not detected in LAL-16-SP1. The analytes not detected are total copper, total organic carbon, total phosphorus, and total aluminum. Similarly for PC1 from his SW17 run, four of the top ten analytes with the largest positive loadings (including the second-largest) were not detected. In this case, the analytes not detected include total phosphorus, total organic carbon, total aluminum, and total dissolved phosphorus.

Additionally, the LAL-16-SP1 sample was non-detect for salmonella species, *staphylococcus aureus*, *brevibacteria* 16S rRNA, nitrate+nitrite as nitrogen, and a number of other parameters. The failure to detect nitrate+nitrite as nitrogen at a detection level of 0.1 mg/L is particularly striking. Not only does this analyte have a significant loading for PC2 in both the SW3 and SW17 analyses, but also, if turkey litter were affecting this spring, one would expect increased nitrogen levels.

Similarly, the Geoprobe[®] groundwater sample associated with the Schwabe farm (GP-GW-10) does not resemble the loadings on PC1 from the SW17 run, the water analysis that included groundwater samples. In particular, of the seven largest loadings, three are not detected, including the second-largest loading for total phosphorus. The other analytes with large loadings but not detected include total iron and total aluminum.

Table 3-2 summarizes these comments regarding samples associated with Cargill contract growers.

Table 3-2. Conclusions regarding samples from Cargill contract growers' facilities used in Dr. Olsen's analyses

Sample Type	Grower		Comment
	Schwabe	Masters	
Poultry Litter	FAC-08	FAC-14	-
Surface Soil	LAL-16-B, LAL-16C, LAL-16D	-	Samples similar to reference (background) soil samples.
Groundwater (Geoprobe [®])	GP-GW-10	-	Concentrations differ from PC1 loadings, with nondetect results for many of the highest loading analytes.
Springs	LAL-16-SP1	-	Likely affected by cattle; concentrations differ from PC1 loadings with non-detect results for the highest loading analytes.
	LAL-16-SP2		Affected by cattle.

In summary, Olsen collected very few Cargill contract grower-specific samples and used only a subset of the resulting data in his analyses. At the one farm where he did collect environmental samples, the number of samples was inappropriately small for the size of the farm. His failure to collect edge-of-field samples or to use groundwater data means that his pathway analysis is incomplete. Further, the data he did analyze do not support allegations of environmental impacts due to turkey litter, because: (1) Cargill contract grower soil samples are consistent

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with reference (background) samples; (2) the presence of cattle at both spring locations confounds any conclusions, and (3) the spring sample he identified as unaffected by cattle, as well as the Geoprobe® groundwater sample, do not show his supposed “poultry litter signature” based on PC loadings.

3.2 Downstream and Downgradient Samples

In Section 5, I present a multimedia PCA based on samples identified by Olsen as usable. In the results for this analysis, I have identified the Schwabe samples and the sole Masters sample, as well as samples downstream and downgradient of Cargill contract growers’ locations that could potentially be affected. The samples used in my analysis are shown in Table 3-3 below. The purpose of identifying locations downstream and downgradient of Cargill contract growers is to see if there is any evidence that samples from these locations differ significantly from reference (background) samples.

Table 3-3. Sample locations downstream or downgradient of Cargill contract growers

Medium	Location	Cargill Contract Grower Upstream or Upgradient	Number of Samples used in PCA Analysis
Springs	SPR-005RPH051206	Bishop	1
	SPR-Anderson	Lester	1
Surface water	BS-62A	Moua	1
	RS-72	Jim Reed (J&J Farm)	1
	RBS-0000109; RS-109	Biggs	2
	RBS-0000148	Breeder 5	1
	RBS-0000150; RS-150	Breeder 5	2
	RBS-0000395	Robert Fisher (King Farm – Hancock Holdings)	1
	RS-399	Bickford	1
	RS-Ballard	Bickford	1
Sediment	SD-033	Biggs	1
	SD-062	Edwards	1
	SD-083	Breeder 5	1
	SD-210	Mitchell; Hurt	1

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4 Critique of Dr. Olsen's Principal Component Analysis

In PCA, the PCs are composed of weighted linear sums of the original analytes (chemicals, bacteria, etc.). A plot of the “loadings” shows how much weight each of the original analytes contributes to a particular PC. In turn, a plot of the “scores” characterizes samples in terms of the PCs.

The key step in Olsen's analysis is his Step 12, where he identifies PCs with sources:

Evaluate whether the major principal components are associated with specific sources. This step consists of two evaluations: 1) comparison of the principal component parameters to the composition of known waste sources and 2) a spatial and temporal analysis of individual principal component scores (for all major principal components). The spatial/ temporal evaluation evaluates principal component scores in relation to the location of the sample (distance from sources), group or environmental component (e.g., edge of field), sample conditions (e.g., high flow, base flow), poultry-house density, and reference locations.

Thus, Dr. Olsen uses the loadings plots to “identify” sources. Once he has identified PC1 as poultry litter and PC2 as WWTPs, he uses the scores plots almost exclusively to estimate the magnitude of the poultry litter source contribution to each sample. He does this by adding a positive number to each score, so that there are no negative numbers and the smallest positive number is +1. Dr. Olsen's report does not describe this adjustment beyond the notation in Appendix F that scores were normalized to 1. He then identifies the largest (adjusted) PC1 score locations as the most affected by poultry litter. He purports in this manner to relate sources to samples. This is an unorthodox, and in my opinion, unscientific use of PCA, for the following reasons.

4.1 Principal components do not represent real entities such as source compositions

PCs are mathematically constrained to be orthogonal (i.e., at right angles) to each other in a multidimensional space. Because of this mathematical constraint, PCs do not represent real entities, such as the typical composition of a particular waste type. This is evident from the fact that PC loadings usually have both negative and positive weights for the analytes. In more advanced methods, such as polytopic vector analysis (PVA), the orthogonality constraint is removed, and the vectors (which play a role similar to the PCs) can represent real quantities. Dr. Olsen did not use any of these more advanced methods.

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4.2 Negative scores are as valid as positive scores

Because PCs do not represent real entities, scores, as well as loadings, can be negative. As noted above, Dr. Olsen removes negative PC scores by adding a positive number to all scores, such that the smallest score for a sample is +1.⁴ This is not a standard procedure when interpreting PCA results. It is not unusual to have negative PC scores that are as large as the positive scores. If the largest negative value is -2 and the largest positive value is +2, Dr. Olsen's procedure would transform the former to +1 and the latter to +5. He then would focus on the +5 as a large value, supposedly indicating poultry waste at that location. However, the original -2 was just as valid and just as important in describing the variability of the data as the +2. Appendix F is titled "Principal Component Scores" but actually provides only the adjusted PC scores, what he terms PC "size." However, his nomenclature is not consistent, because he continues to refer to the adjusted scores (PC size) as PC scores. For example, the first bullet of the spatial analysis section of Dr. Olsen's report (page 6-57) refers to 50 samples with PC scores above a value of 2. Based on output provided by Dr. Olsen for his SW3 PCA run, there are only 13 samples with a PC1 score above 2. There are 49 samples with a PC size (adjusted PC score) above 2.⁵

4.3 Large loadings do not represent large concentrations

An example of fallacious reasoning is found on page 6-56 of Olsen's report. Olsen notes that the largest loadings for PC1 from his SD1 run (Figure 6.11-14b) are for potassium, total phosphorus, sodium, magnesium, water-soluble sulfate, total zinc, soluble salts, Mehlich 3 phosphorus, copper, calcium, organic matter, water-soluble ammonia, water-soluble phosphorus, total nitrogen, *enterococcus*, and *e. coli*. He then notes that "many of these parameters have very large concentrations in poultry waste..." The loadings do not represent the analytes present at the highest concentrations. Rather, the analytes with the largest magnitude (positive or negative) loadings, for a given PC, contribute the most to explaining the variability in samples. For example, suppose there are two analytes, A and B, measured in three samples. The values for analyte A are 7, 8, 9. The values for analyte B in the same units are 100, 100, 100. B is present at higher concentrations than A, but will have a loading of zero, because it does nothing to explain the variability among the three samples.

There is an additional reason that large loadings do not represent large concentrations: Olsen's analyses are based on transformed data, rather than the original concentrations. The original concentration data were transformed by subtracting the average value for the analyte and dividing by the standard deviation of the analyte across all samples. The procedure of dividing by the standard deviation tends to make all adjusted concentrations similar. In addition, the log of the concentration, rather than the measured concentration, was used with some analytes.

⁴ Mudge notes that this practice reduces the usefulness of PC1 as a signature/source discriminator. S.M. Mudge, *Multivariate statistical methods in environmental forensics*, Environmental Forensics **8**, 155-163 (2007).

⁵ There are 50 samples if the adjusted scores are rounded to two decimal places.

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4.4 Errors in Dr. Olsen's PCA Calculations

In conducting his PCA, Dr. Olsen used EDAnalyzer as a “shell” to run Systat statistical software. EDAnalyzer is a program developed by CDM. As indicated by Dr. Olsen, all of the calculations conducted by EDAnalyzer can be conducted outside of EDAnalyzer, and this was done to verify his results. However, following the “Steps of PCA” in Dr. Olsen’s report and using his input files does not produce the results shown in his report. This is due to a fundamental error made by Dr. Olsen. PCA run SW3 is used as an example, to illustrate the nature of this error.

According to Dr. Olsen’s report, the cross-tabulated data set for his PCA run SW3 was saved in a file named “Crosstab_Water_0427_SW_3.xls.” This file contains the original results for the 26 variables and 573 samples identified for this analysis. The number of samples and variables matches the results provided, indicating that this file is the result of Step 8 of his “Steps of PCA” process. Appendix E of Dr. Olsen’s report provides probability plots of the log-transformed values for all 26 variables. This, along with text in his report, indicates that all of the variables were additionally log-transformed as part of Step 8.

Not all samples had values for all variables, a fact that Dr. Olsen treats in an inconsistent way, as described below.

Using the data set described above as input for the PCA run, the output from Systat reproduced the coefficients reported by Dr. Olsen. This is true only when based on a correlation matrix with pairwise deletion.⁶

However, the PC scores reported by Dr. Olsen do not match the scores calculated directly by Systat, nor do they match the result of multiplying the coefficients by the standardized input data set.⁷ Table 4-1 shows these three different computation results for PC1 scores for the first ten samples analyzed.

⁶ When a sample is missing a result for a variable, that sample does not contribute to the relationship between that variable and each other variable. This results in differing numbers of samples defining the relationship (i.e., correlation) between each pair of variables.

⁷ The standardized data set was calculated directly within Systat, because this data set was not provided explicitly within Dr. Olsen’s production files. A description of this standardization was included in Dr. Olsen’s report.

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Table 4-1. PC1 scores for the first ten samples analyzed in PCA run SW3

Sample	PC1 Scores		
	Reported by Dr. Olsen	Systat	Calculated per Dr. Olsen's Report Description
BS-08:8/23/2005:SW:S:-	-0.34148	-	-1.16490
BS-117:9/14/2005:SW:S:-	-0.17746	-0.03203	-0.03677
BS-208:5/1/2007:SW:S:0-	-0.32136	-0.98544	-1.13125
BS-208:9/1/2005:SW:S:-	-0.30778	-	-1.19177
BS-28:8/23/2005:SW:S:-	-0.33048	-	-1.20054
BS-35:5/2/2007:SW:S:0-	-0.27929	-0.37380	-0.42911
BS-35:9/22/2005:SW:S:-	-0.15297	-0.36515	-0.41918
BS-62A:5/1/2007:SW:S:0-	-0.26851	-0.35077	-0.40267
BS-68:5/2/2007:SW:S:0-	-0.31337	-0.43920	-0.50418
BS-HF04:5/1/2007:SW:S:0-	-0.05471	0.09112	0.10460

There are missing entries in the Systat column of Table 4-1 because the Systat software will not calculate a score for samples that have missing data. The calculated values shown in the rightmost column of Table 4-1 are based on multiplying the derived PC1 coefficients times the standardized input data used in the PCA. The calculated scores are proportional to the scores produced directly by Systat, unlike the scores reported by Dr. Olsen.

Based on trial and error, the PC scores reported by Dr. Olsen were reproduced using the score calculation description from his report applied to the original measured values, rather than the log-transformed values from which the coefficients were derived. If the PCA had been done correctly, Dr. Olsen would have used the same data to derive the coefficients as he used to derive the scores. This is a fundamental error made by Dr. Olsen, and it affects all PCA runs of his report and renders all of his results invalid.

4.5 Dr. Olsen does not have a single set of principal components in his pathway analysis

Dr. Olsen claimed in his October 26, 2007, affidavit, and in his September 10, 2008, deposition, that a unique chemical/bacteriological “signature” exists in both the poultry litter and environmental media. However, he used different PCAs for solid (poultry litter, cattle manure, sediment, and soil) and liquid (Geoprobe[®] groundwater, spring, well, edge-of-field, stream, and SPLP) media. Because of this, there is no single “signature” in his analysis that connects the composition of poultry litter samples to that of distant streams in the watershed.

Table 4-1 compares the importance of different analytes found in Cargill contract grower poultry litter with the loadings from the solid and liquid PCA runs completed by Dr. Olsen. All

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loadings are for the “No Rotation” case. As the table makes clear, the important analytes in the liquid analysis loadings are not the same as the important analytes in the solid analysis loadings. Thus, there is no “handoff” along the pathway. The rankings in Table 4-1 go from the largest positive loading to the largest negative loading. Where an analyte does not appear in the ranking, it was not included in that PCA run. Some examples:⁸

- *E. coli* is 1st and 2nd for the liquids analysis rankings, and 13th for the one solids analysis ranking.
- Total iron is ranked 3rd and 5th for the liquids analyses, and 22nd and 23rd for the solids analyses.
- Total aluminum is ranked 6th and 7th in the liquids analyses, and 19th and 28th in the solids analyses.

Conversely:

- Total potassium is 2nd and 5th in the solids analyses, and 9th and 11th in the liquids analyses.
- Total magnesium is ranked 7th and 8th for the solids analyses, and 17th for the liquids analyses.

Thus, the loadings provided by Dr. Olsen do not present a chemical “signature” along the supposed pathway from poultry litter and soils to surface water and groundwater. Dr. Olsen fails to provide any connection between solid and liquid media.

In Section 5 I use a multimedia PCA to see if there is an identifiable signature that carries over from poultry litter to environmental media. I conclude that there is no such signature.

⁸ Not all the differences are between solid and liquid sample rankings. For example, SW3 has total copper ranked number 1, while in SW17, it is ranked 17th. This illustrates the difficulty of using PCA loadings for source identification.

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Table 4-2. Rank order of loadings for PC1 from Dr. Olsen's PCA runs

Analytes included in Olsen's analysis	Rank Order of Loadings for PC1			
	SW3	SW17	SD1	SD6
<i>E. coli</i>	2	1	13	
<i>Enterococcus</i>	9	6	9	
Fecal coliform	8	4	17	
Nitrogen (inorganic + organic)	22	23	16	10
<i>Staphylococcus aureus</i>			26	
Sulfate (water soluble)	21	20	12	
Total aluminum	6	7	28	19
Total arsenic	14	14	21	13
Total barium	19	18	22	14
Total beryllium			24	16
Total chromium			29	20
Total cobalt		21	30	
Total calcium	26	25	14	9
Total copper	1	16	15	7
Total iron	3	5	32	23
Total magnesium	17	17	7	8
Total manganese	13	12	20	12
Total mercury			25	17
Total nickel	7	11	23	15
Total potassium	11	9	2	5
pH			19	11
Alkalinity	25	26		

4.5.1 To identify common sources, loadings have to be looked at in multidimensional space

Olsen presents information for the loadings on PC1 separately from loadings on the other PCs, PC2, PC3, etc. This obscures the actual relationship between analytes. Examining loadings for PC1 alone, he concludes that the largest loadings must have a common source. However, when loadings are examined in a multidimensional PC space, different relationships appear. I illustrate this using PC1 and PC2.

For run SW3, Olsen notes that PC1 has relatively high positive loadings for a large number of variables, including arsenic, total coliforms, copper, *e. coli*, *enterococcus*, iron, fecal coliforms,

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potassium, nickel, total and total dissolved phosphorus, total organic carbon, and zinc. However, when the loadings for PC1 and PC2 are plotted in the conventional presentation, as shown in Figure 4-1, these variables are widely separated with regard to PC2, ranging from about -0.3 to +0.6. Although both total potassium and bacteria have large loadings for PC1, they vary in opposite directions with regard to PC2; with a large positive loading for total potassium compared to large negative loading for bacteria. These analytes do not co-vary. This is not the signature of a single source.⁹

Loadings for the SW17 run, shown in Figure 4-2, show a similar situation. Here, the analytes with large positive PC1 loadings range from -0.4 to +0.5 in PC2 loadings. In both of the liquid analyses (Figures 4-1 and 4-2), the analytes that co-vary plot very close to one another. These include total calcium and alkalinity, total sodium and chlorine, and total, soluble reactive, and dissolved phosphorus. The bacteria species also co-vary. None of these results are unexpected. Zinc, arsenic, and copper are often found together in soils, so it is not surprising to see them in close proximity in these loadings plots, and total organic carbon close by because it is an indicator of soil erosion.

In Olsen's SD1 analysis, shown in Figure 4-3, the loadings plot for solids shows the bacteria species widely separated, with *staphylococcus aureus* and *e. coli* varying opposite to each other on both PC1 and PC2, suggestive of different sources. In this case, analytes with the largest positive loadings in PC1 vary from about -0.5 to +0.2 in PC2. When the bacteria are not included, as in the SD6 analysis, the highest loadings in PC1 vary from 0.1 to 0.6 in PC2, as shown in Figure 4-4.

Overall, the wide variability in PC2 loadings indicates that the analytes with the largest positive PC1 loadings do not have a common source.

⁹ As Mudge, op. cit., states, "If compounds co-vary (behave the same as if they had the same source), in this type of analysis they will have similar loading factors... When compounds come from the same source, these loading factors are numerically similar for each compound and, if these loadings were plotted against each other, will group close together."

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5 Multimedia Principal Component Analysis

As noted in previous sections, there are many flaws in Olsen's selection of analytes and samples, as well as in his actual calculations. In my opinion, some of these flaws are fatal; for example, they involve serious mathematical errors and identification of natural soil components as related to poultry litter. However, in this section, I put those flaws aside in order to show that a multimedia PCA, when run correctly and interpreted properly, leads to entirely different conclusions from those presented by Dr. Olsen.

Olsen keeps PCA of solid and liquid samples separate. However, there is no reason to do this, particularly if he believes that there is a consistent poultry litter "signature" that spans from poultry litter to edge-of-field, groundwater, springs, and surface water. PCA of multiple media are not uncommon in the literature.¹⁰ This section describes a multimedia analysis based on the same data as used by Olsen.

Analytes were considered for inclusion in the multimedia PCA if they were measured in all media (both solid and liquid).¹¹ This excluded, for example, grain size measurements only possible for solid media and dissolved parameters only measurable in liquid media. Samples were included only if more than 50 percent of the analytes were detected. Multiple results for the same sample for the same analyte were averaged (non-detected results included at half the detection limit), regardless of whether detection limits were above detected results. A result was considered non-detect only if all results for that analyte and sample were non-detect. If at least one result was detected, then the average was treated as a detected result.

Parameters measured in both liquid and solid media include total metals (aluminum, arsenic, barium, calcium, copper, iron, potassium, magnesium, manganese, sodium, nickel, and zinc), nitrogen, total phosphorus, bacteria (total coliforms, *e. coli*, *enterococci*, and fecal coliforms), and pH. Results are shown in Figures 5-1 and 5-2. To distinguish this multimedia PCA from Olsen's more limited PCA, I use the terms "MM-PCA" and "MM-PC." Each sample in this analysis is standardized to reflect the percent contribution of each metal to the total metals, the percent nitrogen and percent phosphorus to their sum, the percent contribution of each bacterium to the total bacteria, and pH as is.¹² In this manner, the magnitude of concentrations does not affect the variability.

¹⁰ For example: H. Fiedler, C. Lau, L.-O. Kjeller, and C. Rappe, Patterns and sources of polychlorinated dibenzo-p-dioxin and dibenzofuran found in soil and sediment samples in southern Mississippi, *Chemosphere* **32**, 421-432 (1996); or R.J. Wenning, D.J. Paustenbach, M.A. Harris, and H. Bedbury, Principal components analysis of potential sources of polychlorinated dibenzo-p-dioxin and dibenzofuran residues in surficial sediments from Newark Bay, New Jersey, *Arch. Environ. Contam. Toxicol.* **24**, 271-289 (1993).

¹¹ Dissolved phosphorus and sulfate were measured in both solid and liquid media but were excluded from analysis. Dissolved phosphorus duplicates total phosphorus, which was measured in more samples. Inclusion of sulfate in the analysis resulted in only one stream sediment sample analyzed. Results, including sulfate (i.e., excluding all but one sediment sample), are unchanged from those presented here.

¹² For a discussion of the so-called "proportion" method, see: S.M. Mudge, op. cit.

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5.1 Origins of Sample Variability

With regard to Figures 5-1 and 5-2, the first three MM-PCs account for 58.5% of the total variability among the samples analyzed, with the first two MM-PCs accounting for 49.1%. MM-PC1 distinguishes primarily between media, liquid versus soil and sediment. This division is attributable primarily to aluminum, iron, manganese, barium, and calcium. The soil and sediment samples contain a larger percent of the total metals from aluminum, iron, barium, and manganese, and a smaller percent contribution from calcium, than the liquid samples. In contrast, the liquid samples generally contain less than 1% contribution to total metals from aluminum, iron, barium, and manganese, and contain generally greater than 80% contribution from calcium. As would be expected, the edge-of-field samples lie between the soil samples and the downstream samples, presumably reflecting the fact that these liquid samples have high dissolved and total solids contents.

MM-PC2 defines differences among the various solid media, specifically poultry litter, cattle manure, and soil/sediment. Additionally, the SPLP samples are generally separated from other media. These divisions between media are driven primarily by differences in the ratio of nitrogen to total phosphorus. The SPLP samples contain virtually no nitrogen but do contain phosphorus, whereas the soil and sediment samples contain very little total phosphorus but contain nitrogen. The poultry litter and cattle manure samples fall in between, with a mix of nitrogen and phosphorus, not always in the same proportion. Further separation is attributable to differences in the relative proportion of the four bacteria (to the total) and the relative percent contribution of potassium to total metals. Potassium constitutes greater than 35% of the total metals in poultry litter samples and generally less than 30% in cattle manure. Cattle manure contains roughly even proportions of total coliforms, *e. coli*, and fecal coliform bacteria, whereas poultry-litter samples primarily contain *enterococci* and very low proportions of the other bacteria. There is quite a bit of variability among the poultry litter samples, some with bacteria compositions similar¹³ to cattle manure and others showing the distinction just described.

MM-PC3 further separates sample groups based on the relative proportions of the three bacteria parameters: total coliforms, *e. coli*, and *enterococci*. Additionally, the higher variability among the poultry litter samples becomes evident in the MM-PC plot of MM-PC1 vs. MM-PC3 (Figure 5-2). MM-PC3 begins to identify differences between flowing water and non-flowing well water, with flowing water generally having higher positive MM-PC3 scores, while many of the non-flowing water samples have negative MM-PC3 scores; however, this distinction is minor in comparison to the differences between the solid media. Although there is not complete separation on MM-PC3, cattle manure and poultry litter generally have very different scores. As with the first two MM-PCs, there is wide scatter in the edge-of-field samples with regard to MM-PC3. However, edge-of-field samples generally have scores that fall between soil samples and surface water samples.

¹³ Similar composition does not mean similar bacteria concentrations.

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5.2 Interpretation of the Relationships Among Sample Types

Generally, samples that occupy the same or nearby portions of a PC scores plot are related, and those that occupy different portions of a scores plot are not similar in composition. Dr. Olsen gives an example of this on page 6-56 of his report:

Most important, the PC1 score vs. PC2 score figure (Figure 6.11-20a and c) shows that the cattle manure plots on the figure in a distinctly different group than the poultry waste...These figures show that cattle manure and poultry waste have different and distinct chemical/bacterial signatures.

Based on the scores plot of MM-PC1 vs. MM-PC2 shown in Figure 5-1, soil samples from the Schwabe farm, along with other soil samples where poultry litter was applied, are indistinguishable from the supposed reference or background soil samples. On Figure 5-2, showing scores for MM-PC1 vs. MM-PC3, the Schwabe samples remain indistinguishable from the reference soil samples. All of this indicates that the composition of the Schwabe soil samples is dominated by native soils (i.e., reference soil).

Sediment samples downstream of Cargill contract growers, as well as other sediment samples, are close in proximity to the cluster of soil samples in Figure 5-1; in general however, they lie between the soil samples and the surface-water samples. This pattern is retained on the MM-PC1 vs. MM-PC3 plot (Figure 5-2), although some of the sediment samples (including the Schwabe samples) are like the reference soil samples with lower values of MM-PC3. This indicates that the sediment samples are also primarily composed of native soils.

Edge-of-field samples are broadly distributed with regard to MM-PC1 and MM-PC2 in Figure 5-1, with some occupying the region between cattle manure/poultry litter samples and surface-water samples, and some in the region between soil/sediment samples and surface-water samples. As noted earlier, there are no edge-of-field samples for the Cargill contract growers.

The cattle manure and poultry litter samples occupy fairly distinct regions of the MM-PC1 vs. MM-PC2 plot in Figure 5-1. However, the two edge-of-field samples from cow pastures (with no poultry litter applied) are indistinguishable from the edge-of-field samples from locations where poultry litter was applied. This holds true for the MM-PC1 vs. MM-PC3 plot also (Figure 5-2). In addition, the SPLP samples for cattle manure overlap with the edge-of-field samples in Figures 5-1 and 5.2. These observations suggest that some edge-of-field samples are affected by cattle manure.

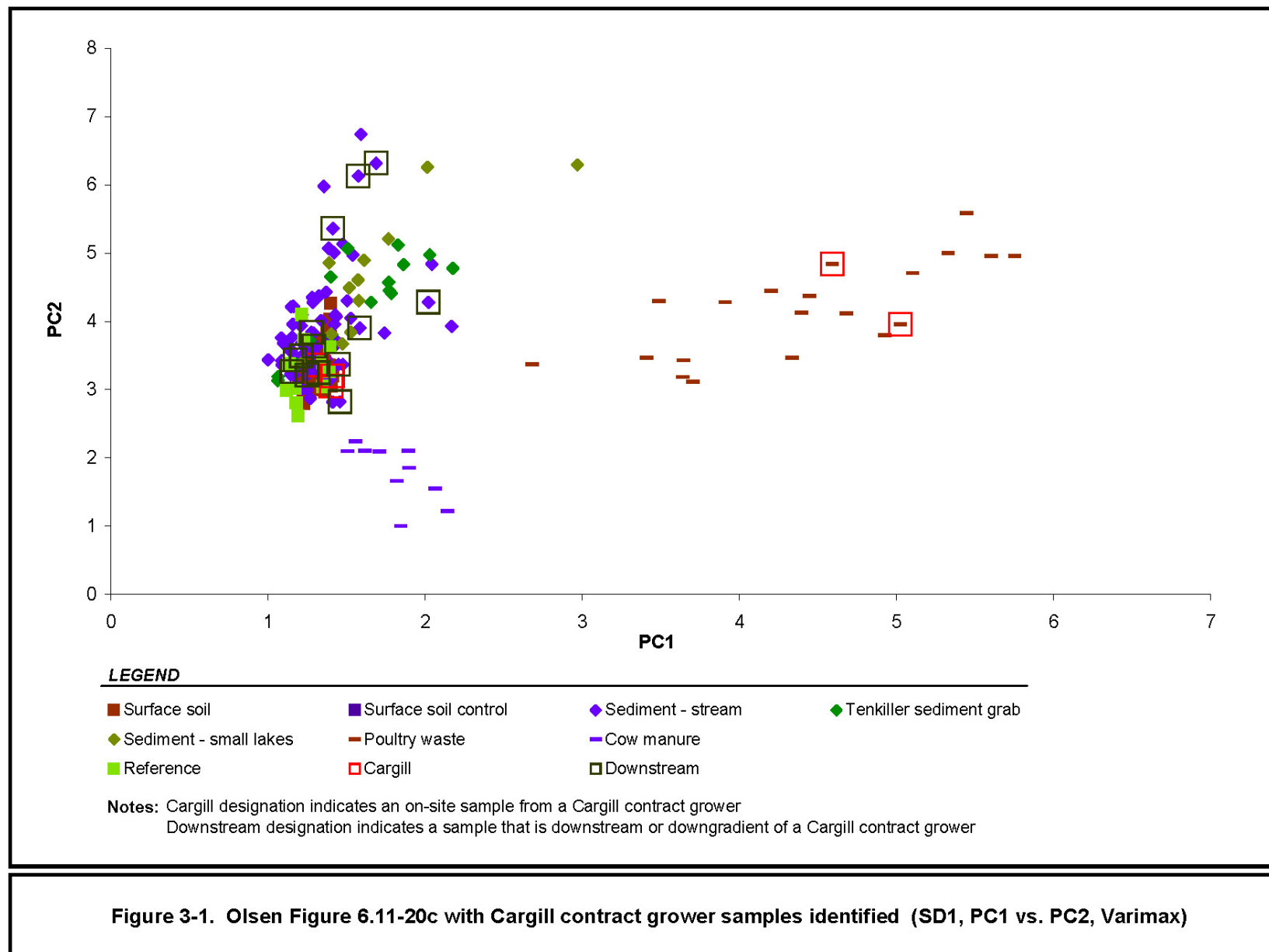
The surface-water samples, including those downstream of the Cargill contract growers and the WWTP samples, are tightly grouped with regard to all three MM-PCs (Figures 5-1 and 5-2). All of these samples have MM-PC scores that are clearly different from the poultry litter samples. Some of the spring and groundwater samples are also in this group, but a few, including the Schwabe samples, are characterized by larger values for MM-PC1. As discussed in Section 3, at least one of the spring samples associated with the Schwabe farm is affected by cattle. The other spring sample and the Geoprobe® groundwater sample have non-detected concentrations for a number of important analytes. In any case, spring and groundwater samples are also clearly distinct from the poultry litter samples.

January 27, 2009

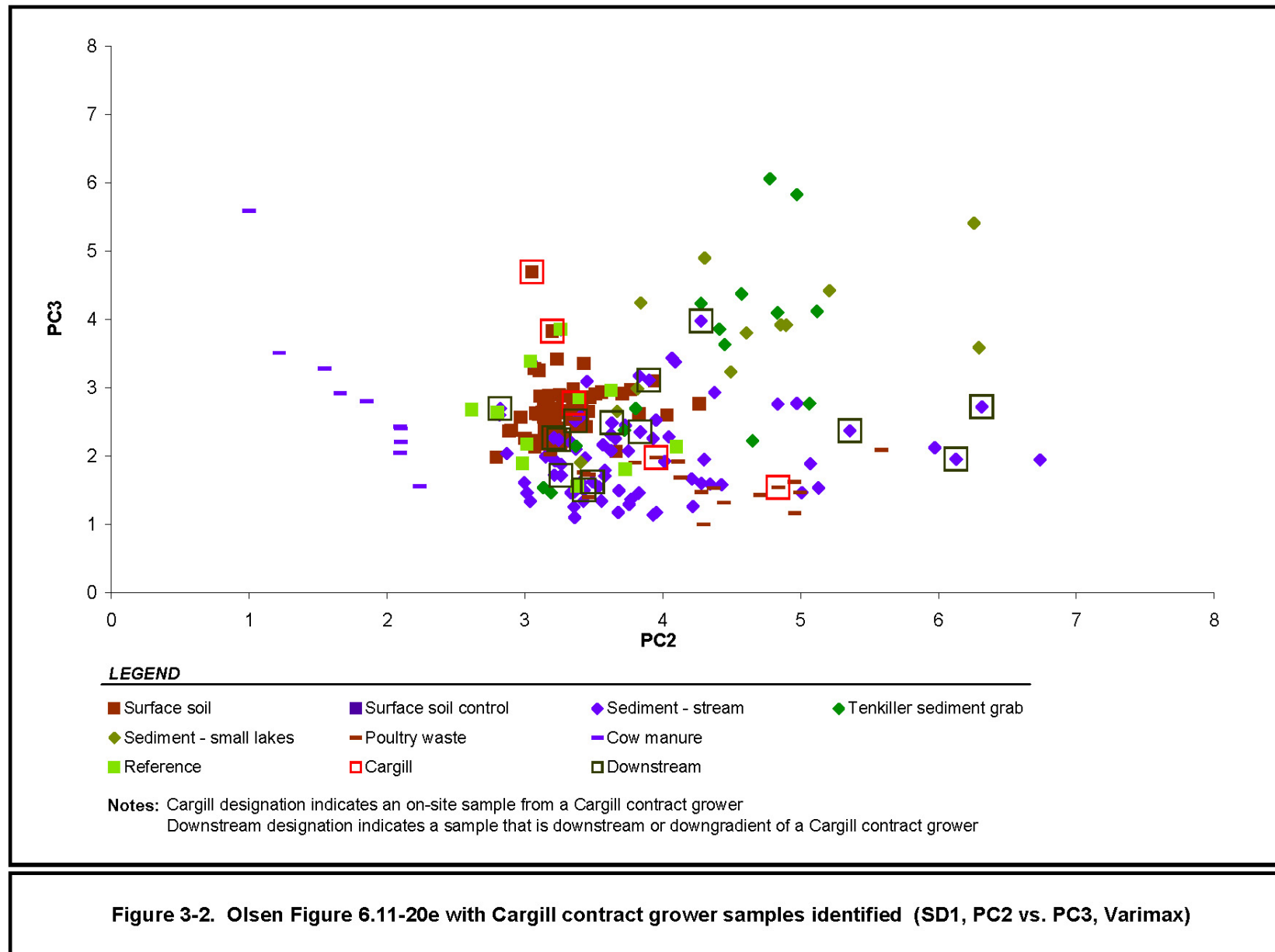
In summary, all of these results demonstrate that using Dr. Olsen's "pathway analysis," there is no unique chemical signature that passes through the media pathway. Instead, the "signature," as defined by the MM-PCA scores plots, changes continuously along this pathway from medium to medium. The multimedia analysis implicates native soils and cattle manure as likely sources of the analytes indicated as important by Dr. Olsen. In particular, for the sole Cargill contract grower where environmental data were collected, Mr. Schwabe, there is no evidence of chemical or bacterial composition related to poultry litter either in onsite groundwater or downstream of this farm.

Figures

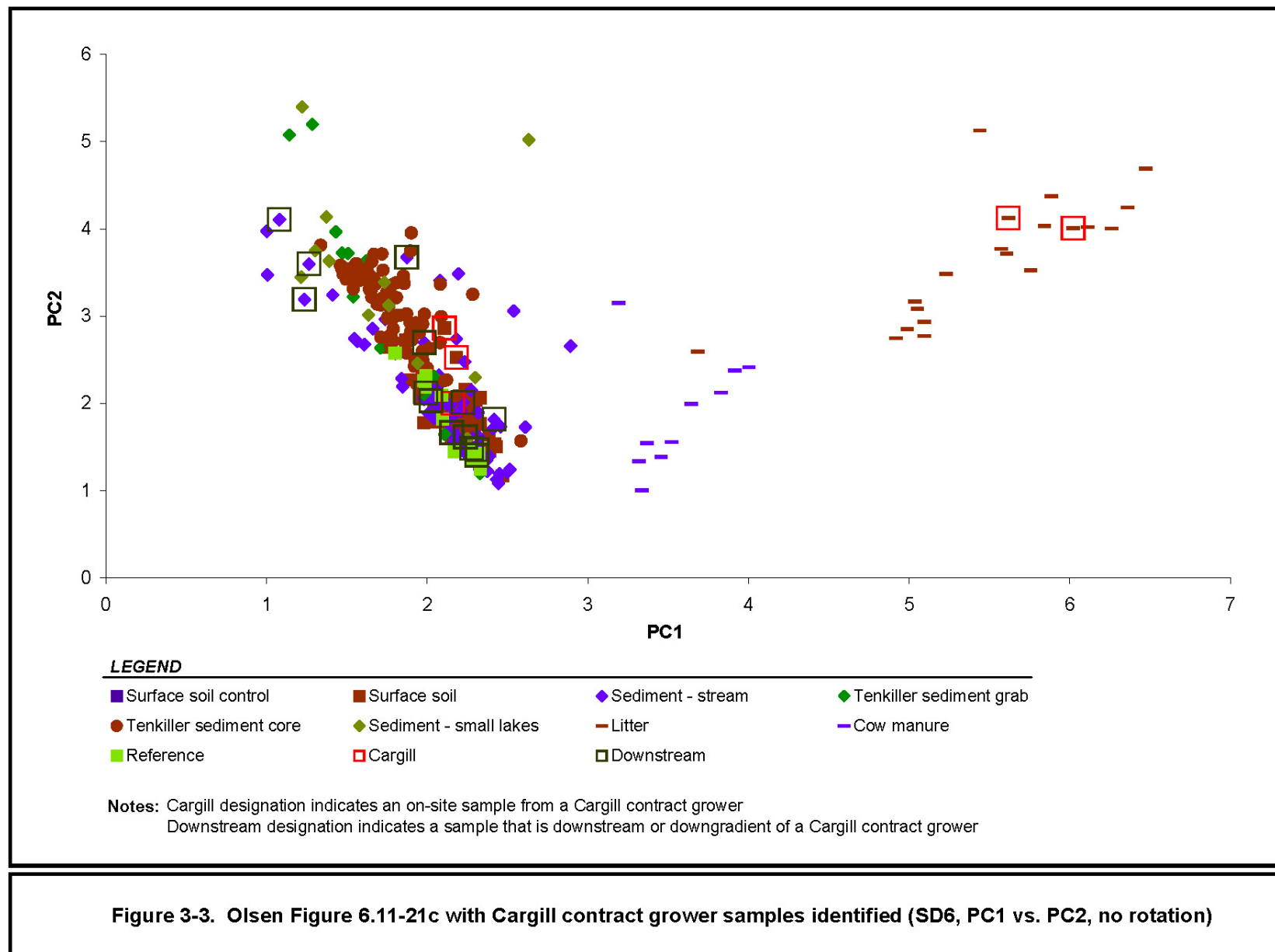
January 27, 2009



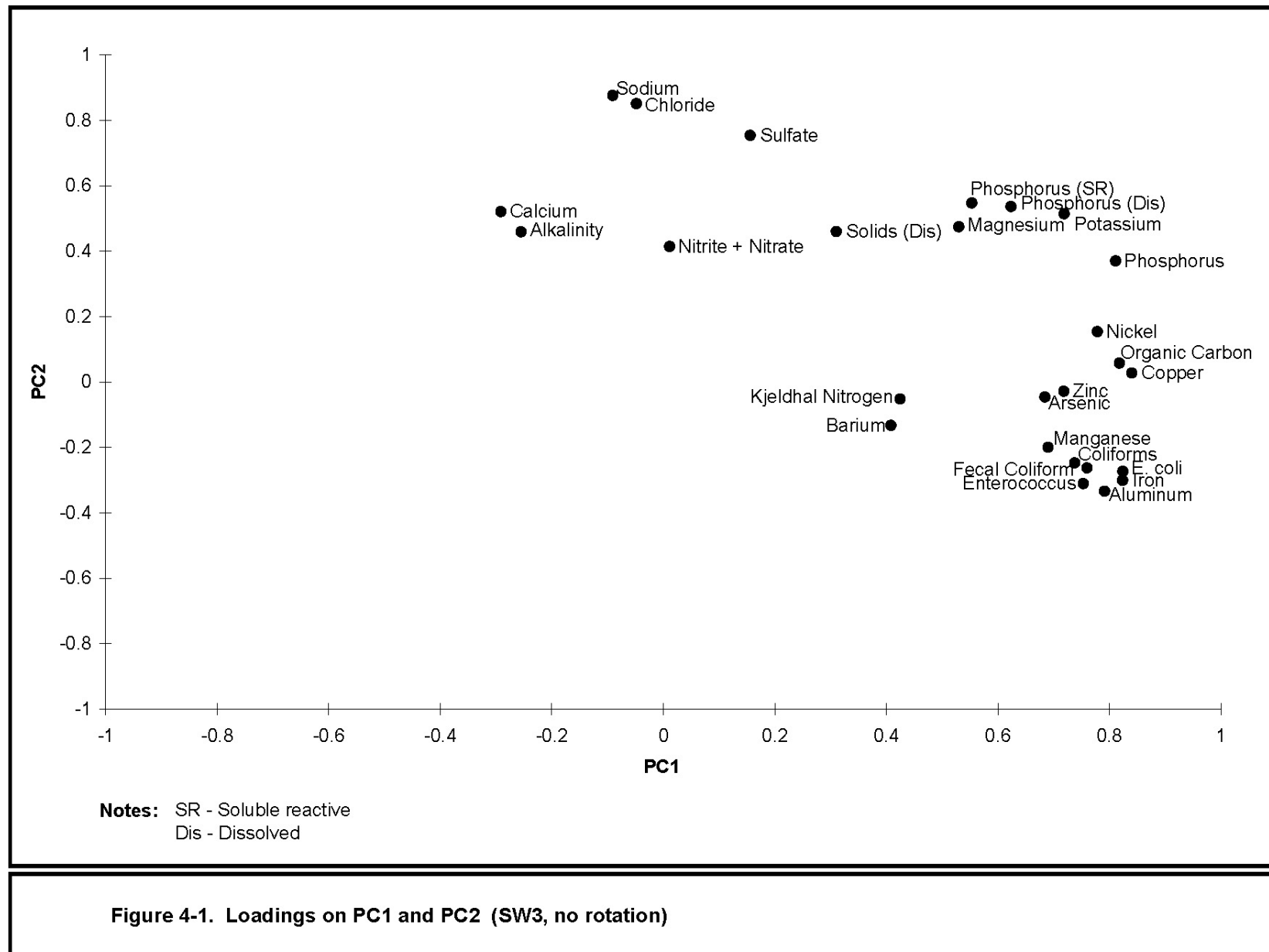
January 27, 2009



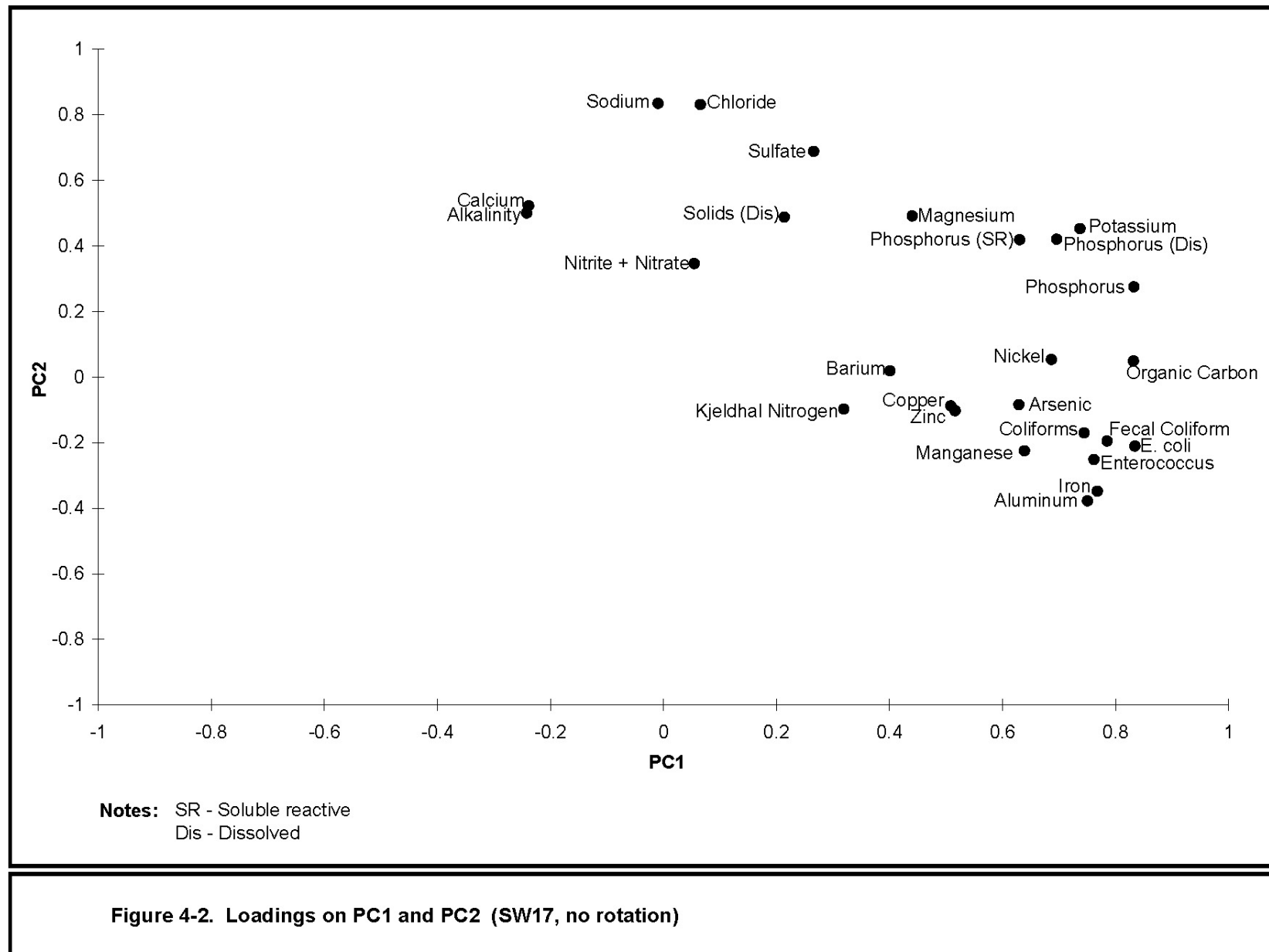
January 27, 2009



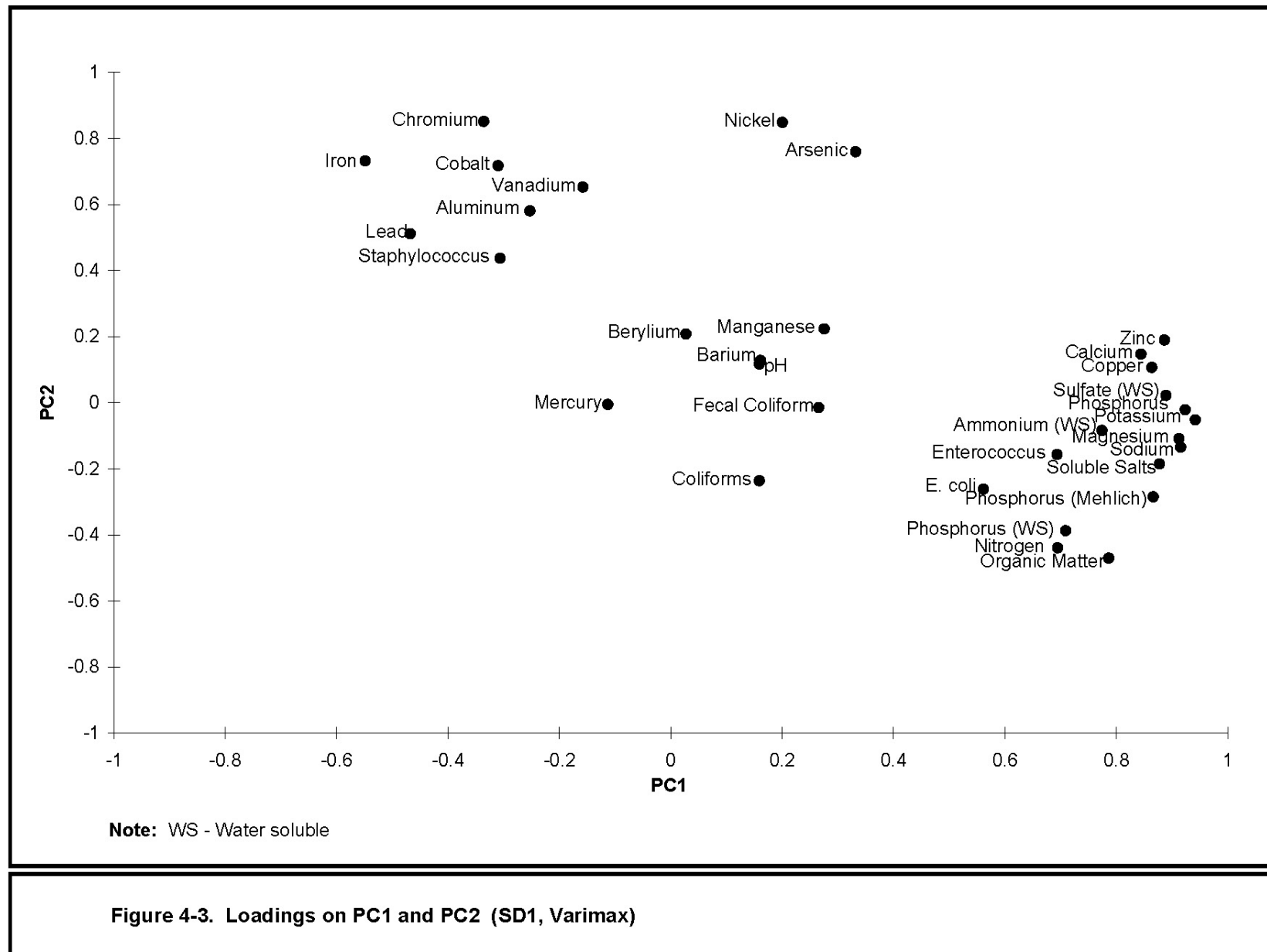
January 27, 2009



January 27, 2009



January 27, 2009



January 27, 2009

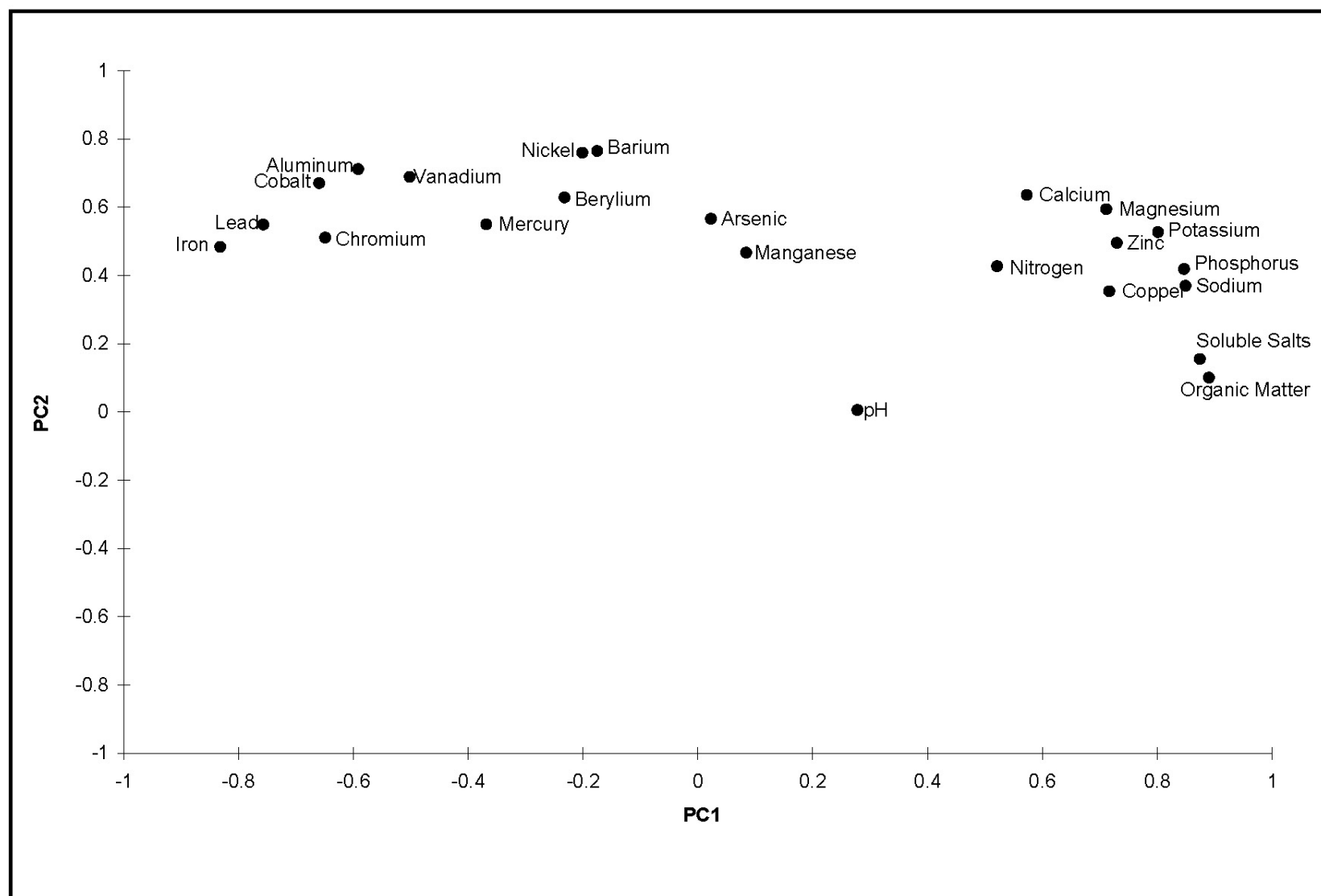
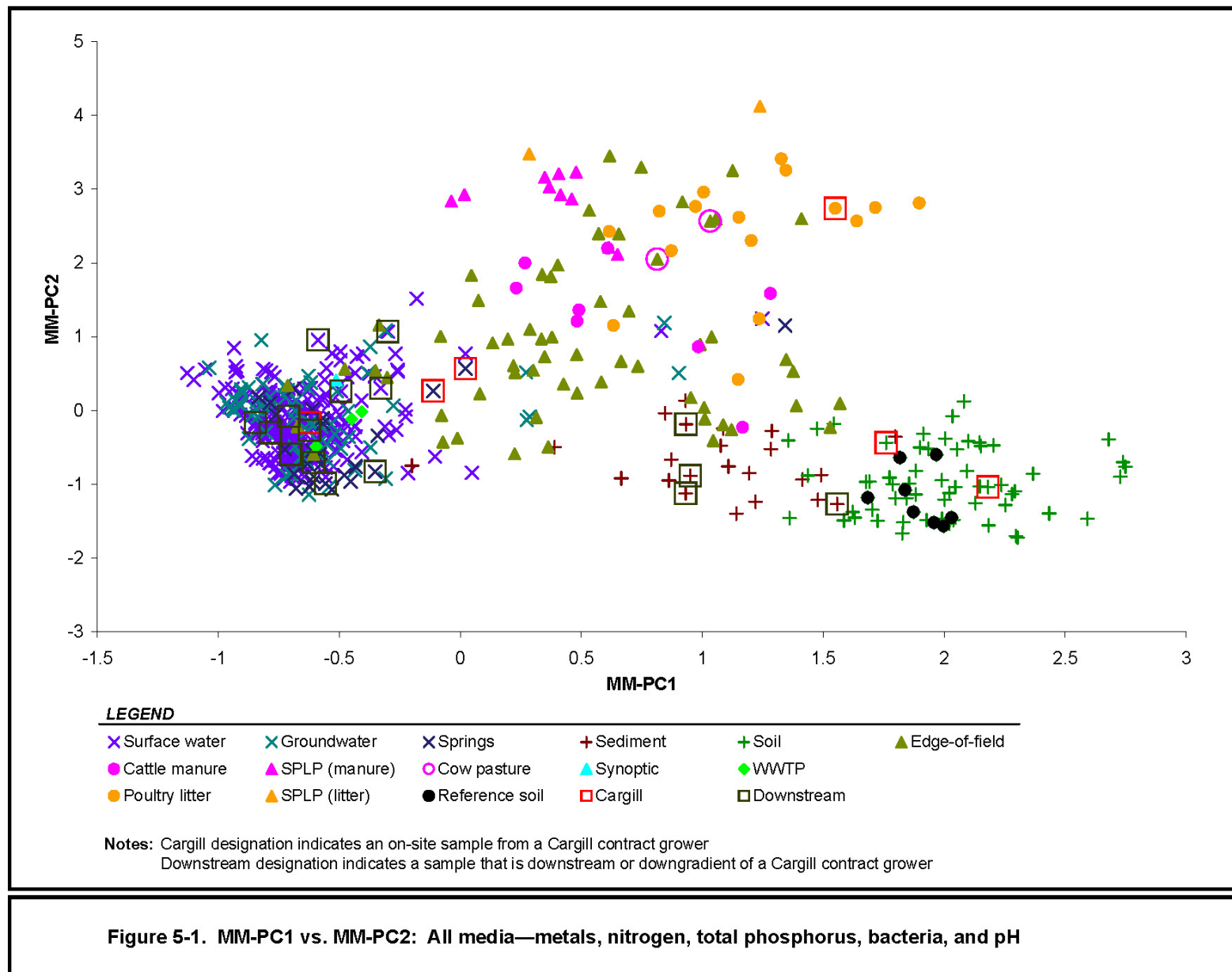
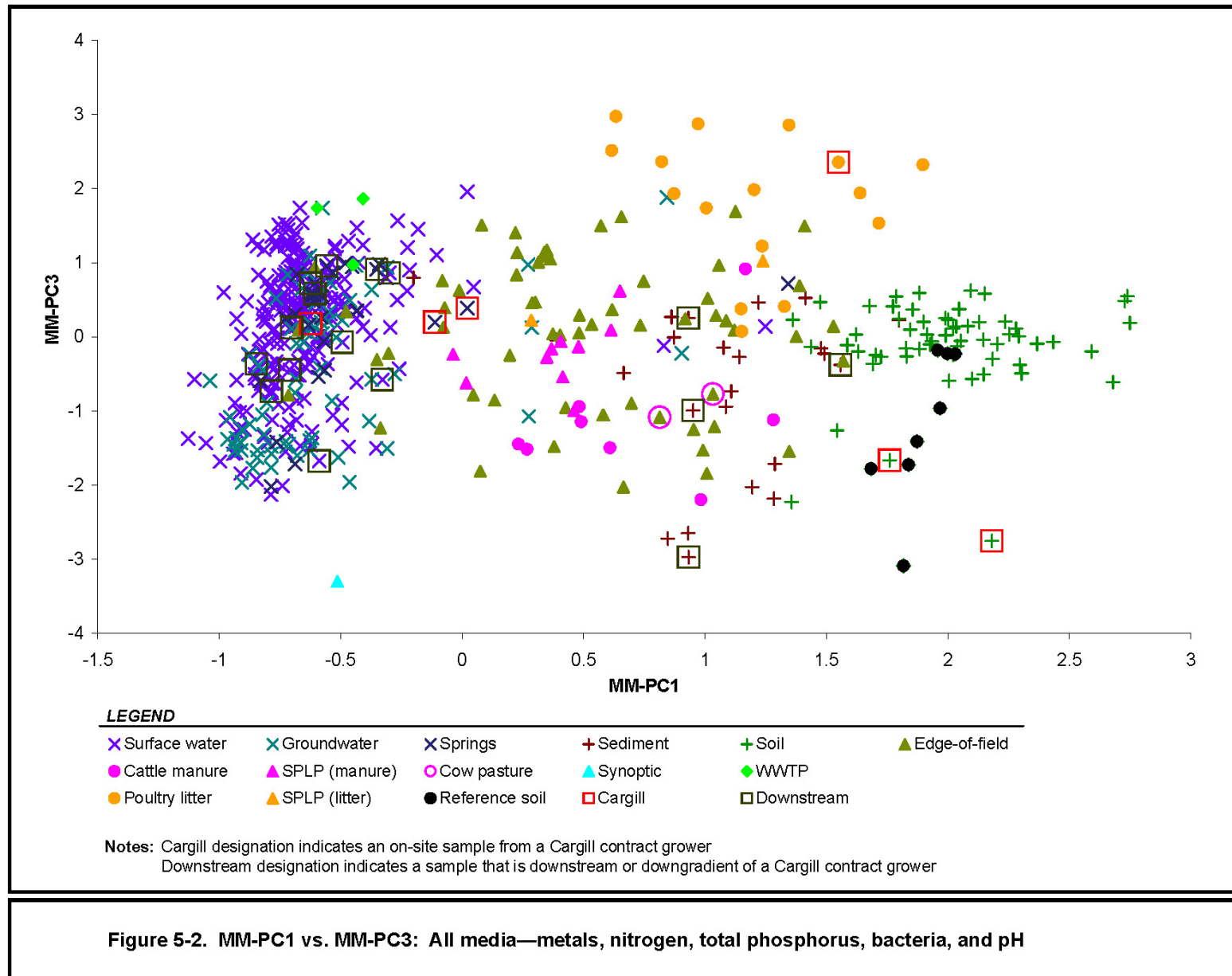


Figure 4-4. Loadings on PC1 and PC2 (SD6, no rotation)

January 27, 2009



January 27, 2009



Attachment A

***Curriculum Vitae* of Brian L. Murphy, Ph.D.**



Brian L. Murphy, Ph.D.
Principal Scientist

Professional Profile

Dr. Brian L. Murphy is a Principal Scientist in Exponent's Environmental Sciences practice. Trained as a physicist, he has more than 30 years of experience in data analysis and mathematical modeling of pollutant fate and transport in various media. He is the author of more than 30 journal publications. He is also coeditor of the Academic Press texts *Introduction to Environmental Forensics* and *Environmental Forensics: Contaminant Specific Guide* and is on the editorial board of the journal *Environmental Forensics*.

Dr. Murphy's practice focuses on:

- Application of environmental forensics methods to assess liability
- Dose reconstruction for toxic torts
- Historical reconstruction of contaminating events at former manufactured gas plants
- Air dispersion modeling, both indoors and outdoors, including soil vapor intrusion
- Use of risk assessment to set clean-up levels and as a cost allocation tool.

Dr. Murphy's projects often involve chlorinated solvents such as PCE, TCE, and TCA; gasoline and other petroleum compounds such as benzene and MTBE; dioxins; metals such as lead and arsenic; and a variety of other compounds, including PAHs, PCBs, radiological compounds, pathogenic compounds, nerve gas, and explosives. He serves as both a testifying and consulting expert in these areas, and his experience also includes formulating challenges to other experts' testimony.

Dr. Murphy has co-chaired several Environmental Forensics conferences and moderated a scientific symposium organized by a citizens group in Palmerton, Pennsylvania, regarding the significance of lead contamination in that town. He has also taught classes on Managing the Superfund Process, Requirements of the Clean Air Act, and Brownfields redevelopment. He has also been a Visiting Instructor at the Harvard School of Public Health and the University of South Florida.

In addition to numerous private-sector clients, Dr. Murphy has been a consultant to the Economic Development Administration of the Commonwealth of Puerto Rico, PEMEX, the North Atlantic Treaty Organization, U.S. Departments of Commerce and Defense, EPA, and the National Academy of Sciences.

Academic Credentials and Professional Honors

Ph.D., Theoretical Physics, Yale University, 1966

M.S., Theoretical Physics, Yale University, 1963

B.S., Physics, Brown University (honors), 1961

Publications

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Morrison RD, Murphy BL (eds). *Environmental Forensics: Contaminant Specific Guide*. Cowrote chapter chlorinated Solvents". Academic Press, San Diego, CA, 2006.

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Project Experience

Criteria Air Pollutants/Visibility

Critiqued the North Dakota State Ambient Air Quality Standards on behalf of the Lignite Energy Council. The State standards were more stringent than federal standards. In particular, the State had a one-hour standard to prevent sulfur dioxide exposure of asthmatics exercising outdoors. Analyzed ambient air monitoring data, air dispersion modeling results, and insurance claims data for the treatment of asthma to support the opinion that risks to asthmatics were extremely small. Made presentations to several State boards and legislative committees, resulting in the elimination of the State standards.

Reviewed a proposal to retrofit older North Dakota power plants to New Source Performance Standards for the Lignite Energy Council. The review focused on the actual contribution of older plants to statewide emissions and ambient air concentrations.

Analyzed regional United States population exposure and potential mortality due to airborne particulate exposure, including uncertainty analysis, in a program sponsored by the U.S. Department of Energy at the Harvard School of Public Health.

Developed a site-specific dispersion model for Proctor and Gamble for a factory in a deep valley, where monitoring showed high concentrations of sulfur dioxide to occur during stable, nighttime conditions.

Conducted dispersion modeling of all Duke Power and Carolina Power and Light facilities in North Carolina, and provided testimony in state hearings regarding a proposed change in particulate standards.

Conducted downwash modeling and dispersion analysis to determine causes and appropriate solutions to a mill odor problem.

Conducted a prevention-of-significant-deterioration (PSD) study for Chevron Chemical at an Iowa fertilizer plant.

Provided dispersion modeling and testimony for Union Camp Corporation for a particulate emission variance in Ohio. Also, assisted in PSD permitting for a new mill in Alabama.

Prepared an uncertainty analysis for particulate concentrations due to surface coal mines for the National Coal Association. Analyzed and combined uncertainties in fugitive dust emission factors, dispersion models, and activity factors to arrive at an overall prediction uncertainty.

Conducted a series of studies evaluating the effect of Amendments to the Clean Air Act on growth in various industrial sectors for the Utility Air Regulatory Group, the American Paper Institute, and the U.S. Department of Energy.

Developed a site location inventory for new power plants in the State of Ohio, through dispersion modeling and other considerations such as water availability, under proposed Clean Air Act Amendments. Work was sponsored by a group of Ohio utilities and was presented to members of Congress and staff.

Developed a modeling and screening procedure for the U.S. Department of Energy to identify visibility impairment—both visual range reduction and discoloration—from air pollutants due to industrial sources.

Evaluated whether or not a potential paper mill acquisition would be permitted by regulatory agencies to convert to coal. Issues related to Clean Air Act compliance and the necessity of installing control equipment.

Conducted plume dispersion and visibility modeling for a power plant near a national wilderness area as part of a lawsuit brought against Public Service of Colorado, Salt River Project, and PacifiCorp.

Retained by Steptoe and Johnson to conduct plume rise analysis for cooling towers at a Chevron Chemical plant in Texas. The purpose was to determine the potential contribution from cooling towers to fog formation along a nearby highway. Concluded that under the meteorologic conditions existing at the time, the plume would have risen vertically, rather than moving horizontally to obscure the highway. Deposed before the case settled.

Dioxins/Furans

Conducted a risk analysis for EPA at the dioxin- and pesticide-contaminated Baird and McGuire site in Holbrook, Massachusetts.

Retained by a citizens' group in Thomaston, Maine, to review environmental impacts due to burning hazardous waste in a rotary cement kiln. Dioxin formation in the kiln, lead contamination of surface waters, and transportation-related fires were examined.

Retained on behalf of Akzo Reliance at the Harvey Industries site in Athens, Texas. The issue was dioxin and furan formation from combusting spent solvents in a boiler and from open burning of solvents. Conducted dispersion modeling and analyzed soil contamination patterns to show that these processes were negligible contributors to the regional dioxin background.

Reviewed the OLM and VHS models used by EPA to develop regulations for leaching and transport of dioxins from burial of incinerator ash. The work was supported by Syntex chemical. Results were presented at an international dioxin conference in Sweden.

Retained by Strasburger and Price on behalf of General Motors to compile emissions inventories and conduct dispersion modeling for three General Motors plants in Matamoros, Mexico, as part of a toxic tort case in Brownsville, Texas. Also analyzed the downwind concentrations of dioxins and other combustion products that would result from open burning of plant wastes at a municipal dump. Compared model concentrations with concentrations of the same chemicals to which people elsewhere are normally exposed. Deposited before the case settled.

Estimated chemical emissions, including metals and dioxins, at a metals reclamation facility in Muskogee, Oklahoma, for the U.S. Department of Justice. Modeled air dispersion and deposition of contaminants into nearby lakes and streams as part of a NPDES suit.

Retained by Hartline, Dacus, Dreyer and Kern on behalf of General Tire in a toxic tort in Odessa, Texas. Estimated chemical emissions and performed air dispersion modeling at a rubber manufacturing facility. Modeled dioxin emissions from an onsite incinerator and hydrogen sulfide emissions from solar evaporation ponds, as well as styrene and butadiene process emissions.

At an abandoned refinery that had leased space to a wood treating plant, analyzed how and when dioxins were transported off site.

Engineered Structures Risk Analysis

Performed a detailed analysis of the likelihood of oil spills, fires, and explosions associated with a proposed oil port in Puget Sound, including tanker and terrestrial and submarine pipeline components. Also conducted oil spill trajectory modeling studies. Provided more than a week of testimony and cross-examination on behalf of Northern Tier Pipeline Company on these topics before the Washington State Energy Facility Siting Commission.

Helped develop a worldwide database for outer continental shelf activity related to oil spills for the U.S. Geological Survey. Collected accident data for oil ports, rigs, submarine pipelines,

single-buoy moorings, and tankers, and developed statistical tests to determine the most appropriate exposure variables and to find evidence of trends.

Developed estimates for the Bureau of Land Management of the oil spill probability and probable magnitude of release associated with tanker traffic for the proposed SOHIO Oil Port in Long Beach. Special problems associated with tanker operations in Port Valdez, Alaska, were included. Predicted that one major spill would occur during the lifetime of the project, probably associated with icebergs in the shipping channel.

Examined the probability of a terrestrial pipeline failure and potential groundwater contamination for a proposed oil port in the state of Tabasco, as well as fire and explosion hazards associated with pipeline operations. Work was sponsored by Petroleos Mexicanos.

Carried out an assessment of the public risk involved in the operation of a liquid natural gas storage facility in Massachusetts. Estimated the probability of occurrence of various initiating events such as earthquake, hurricane, and sabotage; modeled the vapor cloud motion in the event of a release; and estimated the probability of ignition and subsequent damage that could occur.

Evaluated records of tank failures in a solvent storage facility in Massachusetts over a 50-year period, and then developed a model for probable tank lifetime and expected time to failure. This model was used to determine the consequences of replacing all the tanks in the farm, replacing the older tanks, or taking no action.

Explosive Compounds/Nerve Gas

Developed bioconcentration factors for the explosive compound RDX in garden vegetables based on a review of the literature. Work sponsored by The Ensign-Bickford Company and the Spanish Fork Technical Committee.

Conducted a multipathway risk assessment for explosive compounds (RDX, HMX, TNT, DNT, nitroglycerin, TEGDN, BTTN, PETN, DEGDN, and TMETN) in groundwater at a site in Utah on behalf of The Ensign-Bickford Company. Developed toxicity factors for a variety of endpoints where these were either absent or inappropriate.

Responded to an EPA request for information as part of listing PETN as a high-production-volume chemical on behalf of The Ensign-Bickford Company.

Assisted the law firms of Parsons Bailey and Latimer and Leboeuf, Lamb, Greene and MacRae in defense of a toxic tort involving possible exposure to RDX and other explosive compounds.

Retained by the Commissioner of Health and Hospitals of the City of Cambridge, Massachusetts, to analyze risks to the public from experiments with chemical warfare agents at a laboratory within the city. Conducted dispersion (puff) modeling to determine the maximum number of people that could be killed in an air release.

Indoor Air Contaminants

Estimated indoor air concentrations due to soil vapor intrusion for homes above a chlorinated solvent plume near Denver.

Conducted a study of indoor air pollutants and associated health effects for the Electric Power Research Institute. The purpose of the study was to determine whether meaningful risk analysis could be done for residential weatherization programs. Pollutants studied include formaldehyde, nitrogen dioxide, radon, and tobacco smoke.

Conducted several air modeling studies and prepared an affidavit for EPA relating to the Hyde Park hazardous waste landfill in Niagara Falls, New York. Topics included potential indoor air concentrations due to contaminated groundwater, air impacts of excavation, air concentrations due to flowing contaminated surface water, and emissions and concentrations resulting from incineration of waste.

Conducted a study of outdoor/indoor chemical migration factors for EPA. Migration pathways included transport of contaminants into basements and living spaces from ambient air, soil water, soil vapor, and surface dust.

Estimated inhalation, dermal, and ingestion exposure from showering, bathing, and general use of groundwater containing chlorinated solvents near a circuit board manufacturing site in Boulder, Colorado. Indoor air modeling and risk assessment were also conducted as part of this toxic tort. Deposed and testified in court regarding how EPA sets drinking water standards.

Determined the indoor air exposures that would occur to occupants if different types of buildings (i.e., office, parking garage) were constructed over a former manufactured gas plant site. Study conducted for a California utility.

Calculated employee exposure in a factory where floors were washed with TCE.

Metals/Inorganics

Performed statistical analysis to identify sources of lead and arsenic at a mid-Atlantic phosphate plant.

Retained by Strasburger and Price on behalf of Norton Performance Plastics in a toxic tort in Odessa, Texas. Estimated indoor air concentrations of mercury in a laboratory as part of a worker exposure case.

Retained by Sagaser, Franson, and Jones on behalf of the Halliburton Company in a toxic tort at a California gold mine. Estimated mercury emissions and ambient air concentrations from blasting ore containing cinnabar. Dispersion was modeled as a puff released from within a pit. Also investigated the relative toxicity of different mercury species.

Acted as Newmont Mining Company's representative on a Technical Advisory Group, which developed risk-based cleanup levels for lead and arsenic in Leadville, Colorado.

Conducted a review of documented public health effects possibly attributable to various mining, milling, refining, and smelting operations for the American Mining Congress. Also provided a theoretical analysis of exposure and expected public health impacts from mining-related sources. This study was motivated by impending RCRA regulation.

Provided risk assessment support to ARCO Coal Corporation for several mining-related Superfund sites in the Western U.S. Lead and arsenic were the principal contaminants of concern.

Developed cost allocation information at the Lowry Landfill in Denver based on legal theories of separability of harm for Alumet Corporation and Shell Chemical. A risk-based analysis showed that these parties' contribution to risk, particularly for the foreseeable future, was minimal and permitted a favorable settlement with the other PRPs.

Retained by Honigman, Miller to identify whether the source of lead at a Michigan site was airborne or due to a nearby landfill. Analysis was based on statistical evidence of enhancement of building drip-line concentrations, characteristic of an airborne source.

Reviewed mining sites proposed for the National Priority List for the American Mining Congress and compared these with a group of non-mining sites also proposed. The purpose was to determine whether there were biases associated with application of the Hazard Ranking System to mining sites. As part of the analysis, developed a risk-based ranking model.

Retained by Sherman and Howard to conduct a critical review of an EPA risk assessment for a tailings pile at the Colorado School of Mines Research Institute. Exposure routes included wind-blown particulate, direct gamma radiation, and tailings ingestion.

PAHs/PCBs

Identified historical operations leading to contamination and assessed the potential for additional offsite migration at more than 25 former manufactured gas plant sites on in New York and Massachusetts on behalf of the utility insurers. Deposited numerous times regarding the circumstances in which tar and other materials were placed in the environment.

Reviewed historical information and contaminant data for a manufactured gas plant in Florida as part of a cost allocation case. Deposited regarding the time periods when releases to the environment likely occurred.

Reviewed potential exposure routes and health effects for coal-tar-related compounds discharging to the Island End River site in Boston Harbor.

Conducted indoor air transport calculations for a western utility in order to estimate exposures that would result for different types of buildings if they were constructed over a former manufactured gas plant site.

Provided exposure and risk assessment information to EPA for the Hocomonco Pond Superfund site in Westborough, Massachusetts. Contaminants included creosote, coal tar, and related

PAHs. Exposure scenarios included ingestion of groundwater, soils, or muck; ingestion of fish; and ingestion of water while swimming.

Developed a comprehensive multimedia exposure model handbook for the Gas Research Institute. The purpose of the handbook was to assist utilities in remediating former manufactured gas plant sites.

Provided litigation support for a wood-treating site in Georgia. Chemicals of concern included pentachlorophenol, creosote, and arsenic.

Determined the likelihood of imminent release through leaching of PCBs in pipeline liquids disposal pits. Work was conducted on behalf of the insurers of Texas Eastern Pipeline.

Estimated air toxics emissions from incineration of wood tar at the Kerry Chemical site for the New York State Department of Environmental Conservation. Also estimated odors that would result from site excavation.

Determined the source of creosote chemicals in groundwater at a site in Florida by analyzing the spatial distribution of contaminants. Candidate sources were a wood-treating facility and an unloading operation at a railroad spur.

Petroleum Compounds

Age-dated petroleum releases at approximately 30 Florida gasoline stations based on the record of equipment failures, plume development, and ratios of plume constituents.

Analyzed benzene exposure from ambient and indoor air for a resident living near a refinery.

Investigated the source and timing of gasoline storage-tank releases at 7-11 convenience stores located in Berkeley, California; Houston, Texas; and Windham, Maine; for Southland Corporation. Techniques included mass-balance checks against missing inventory, ratio analysis of BTEX compounds, presence of tracers such as lead or MTBE, and estimating release date from MTBE plume extent.

On behalf of the American Petroleum Institute, conducted a critical review of EPA's Liner Location Model. This model was used in development of regulations for groundwater releases from mud pits and reinjection wells.

Reviewed how the Hazard Ranking System was applied at a Bossier City, Louisiana, refinery site for Occidental Petroleum.

Conducted a study for the National Academy of Sciences of the cost/benefit relationships involved in regulations controlling the discharge of oil from offshore drilling platforms. This required an assessment of energy and natural resource depletion factors, as well as economic and environmental impacts.

Conducted an assessment of the potential market for anthracite coal, under alternative formulations of New Sources Performance Standards for the U.S. Department of Energy.

Determined community exposure and risks at a municipal landfill where toxic chemicals were disposed and were being advected with the methane generated in the landfill. The analysis was performed for the City of New York at a Staten Island site.

Evaluated whether or not a potential acquisition would be permitted by regulatory agencies to convert to coal for a paper company.

Developed a national model for energy consumption due to environmental controls in the fossil-fuel-fired steam electric industry for the U.S. Department of Commerce.

Solvents

Determined exposure levels for nearby residents due to solvent wastes stored at a Texas site, as part of a toxic tort.

Analyzed how and when chlorinated solvents entered the environment at a Kansas manufacturing facility.

Retained as an expert witness and was deposed for a source determination case in the U.S. Virgin Islands. Analyzed chlorinated solvent biodegradation product ratios for perchloroethylene (PCE) and daughter products trichloroethylene (TCE) and 1,2-dichloroethylene (1,2-DCE). Both anaerobic and aerobic biodegradation were important. The purpose of the ratio analysis was to determine the relative contribution from a small release at a dry-cleaning facility to the total contamination observed in a large groundwater plume.

Estimated methylene chloride exposures near a manufacturing facility based on a variety of monitoring data and dispersion modeling results.

Deposed on how and when TCE and 1,1,1-trichloroethane (TCA) were released from a vapor degreasing operation at a manufacturing facility in Nebraska. The analysis was based on mass-balance calculations and groundwater plume analysis, as well as solvent purchase records and inspection of the degreaser.

At the Salt River Project in Phoenix, Arizona, performed multimedia (three-phase) modeling to show that surface soils were being contaminated with TCE from a groundwater plume, rather than the contaminated soils being evidence of a spill that led to groundwater contamination.

Retained by U.S. Department of Justice to estimate indoor air exposures resulting from a solvent-contaminated groundwater plume in Colorado. Calibrated a soil vapor intrusion model for plaintiffs' homes with measurements made at nearby homes. Filed an affidavit reporting results.

Analyzed the spatial distribution of TCE and its biodegradation daughter products in groundwater, to help distinguish between residential septic tanks, a nearby landfill, and a manufacturing facility as sources of contamination at a site in Florida. This work involved a historical review of the use of septic tank cleaners containing chlorinated solvents.

Analyzed PCE data at a dry-cleaning facility in a Los Angeles-area strip mall. No biodegradation products were found in soils or groundwater. That, plus the operating history, led to the conclusion that the release had been of fresh PCE rather than spent. This helped to identify the responsible parties.

At a New Orleans dry cleaner, determined that soil and groundwater contamination had originated with a separator connected to a lateral line to the sanitary sewer. This determination was made based on the pattern of contamination and historical information about dry-cleaning operations.

Our client had operated a degreaser at a facility in the Denver area. However, there was no record of their using PCE. Based on their historical standard operating procedures, we determined that a previous tenant, a defense contractor, had operated a portable PCE degreaser for cleaning precious metals electronic parts. This enabled a settlement between the parties. .

Retained by Grace Chemical Company and deposed as an expert witness in the Wells G and H toxic tort case in Woburn, Massachusetts. Examined groundwater data to determine possible sources of TCE contamination. Also analyzed the city water distribution system to determine exposures to TCE from drinking water and household water uses such as showering.

Conducted groundwater modeling to determine the time of plume origin and the time when solvent contamination reached site boundaries, at the Marotta Scientific Controls site in New Jersey.

Retained as an expert witness regarding the time of origin of a 1,1-dichloroethylene (1,1-DCE) plume in Palo Alto, California. The plume originated by hydrolysis of the degreasing agent TCA in relatively warm groundwater. The analysis was based on the fact that installation of a remediation well had left a "signature" in the plume, making a direct measurement of the contaminant velocity possible in spite of a complex hydrogeologic setting. Was deposed and testified in court.

Determined the timing of releases to groundwater and the sources of solvent and chromium contamination leading to closure of drinking-water wells near Camden, New Jersey. To determine the sources of contamination, both mass-balance estimates and groundwater modeling were used.

Determined how long it would take to remove volatile organic compounds through *in situ* soil washing on behalf of a PRP group at the Liquid Disposal, Inc., Site in Michigan. These calculations were the basis for overturning a Record of Decision that had called for excavation and removal of soils.

Assessed risks due to offsite groundwater contamination by solvents and compounds related to chemical weapons manufacturing at the Rocky Mountain Arsenal in Colorado, for the State of Colorado.

Evaluated the public health significance of leachate measurements near the Cohasset Heights Landfill in Massachusetts and presented the results before two town boards.

Retained by Strasburger and Price to model chemical emissions from three General Motors automotive parts manufacturing plants and a waste dump in Matamoros, Mexico. Deposed regarding potential exposures of residents in nearby Brownsville, Texas, and how those exposures compared to everyday household exposures to the same chemicals, as part of a toxic tort anencephaly case.

Retained as an expert witness by McKenna and Cuneo and the U.S. Department of Justice on behalf of Thiokol Corporation and the U.S. Army. Performed critical review of worker and public exposure estimates from vapor degreasing operations at the Longhorn Army Ammunition Plant, in Texas. The case involved deposition testimony and participation in a Daubert hearing.

Retained by Woodard, Hall and Primm on behalf of Monsanto to model emissions from chemicals buried in pits and other sources at the Brio Superfund Site in Texas. Other technical analysis has varied during the course of involvement in about half a dozen separate toxic torts involving worker as well as public health claims. Deposed on numerous occasions and, on one occasion, testified in court. The primary substances of concern have been 1,1,2-trichlorethane, 1,2-dichloroethane, and vinyl chloride.

Conducted a literature review and developed air emission models for volatile organic compounds, using a consistent mass transfer theory approach for lagoons, landfills, landfarms, and holding facilities. This work was sponsored by EPA and was published in book form by Noyes Data Publishing.

Retained by the New York State Department of Health to analyze emissions and risks from operation of an air stripper. Key compounds were tetrachloroethylene and byproducts from disinfection by chlorine.

Combined monitoring data and dispersion modeling to determine solvent and petroleum compound exposures for civilian workers at a wastewater treatment plant at the Pensacola Naval Air Station in Florida. Retained by the U.S. Navy and testified before an arbiter.

Estimated volatile and semivolatile compound emissions from a proposed groundwater air stripper system and from landfill gas flares, as part of a Minnesota landfill expansion for Browning Ferris Industries. Dispersion modeling was used to determine nearby population exposure. Testified before an Administrative Law Judge.

Provided risk assessment consulting for submittal of a RCRA corrective action report at a hazardous waste incinerator site in Ohio.

Retained by Sherman and Howard and Davis Graham and Stubbs in connection with the Redfield Rifle site in Denver, Colorado. Estimated the health risks from exposure to 1,1-dichloroethylene in indoor air at residences located above a groundwater plume. Risks from 1,1-dichloroethylene were compared to risks from radon and chloroform. Determined appropriate action levels and attended public meetings to communicate results to potentially affected residents. Subsequently was deposed regarding U.S. EPA revisions to the toxicity profile for 1,1-dichloroethylene as part of a toxic tort case at this site. As part of an allocation issue, also determined which chlorinated solvents had been used during which time periods of different site occupancy.

Miscellaneous

Determined the origin and transport of hydrogen sulfide gas as part of an injury case at a paper mill in Maine.

Determined carbon monoxide plume trajectory for an RV generator parked next to a fifth-wheel trailer as part of a carbon monoxide death case.

Developed an objective screening criterion for rank ordering potential hazardous waste disposers for an electronics manufacturer. Physical criteria, which accompanied financial and management criteria, were based on chemical release and fire/explosion risk models.

Surveyed applications of meteorology in energy conservation programs. Results were intended to help guide National Science Foundation meteorology research and development.

Reviewed environmental studies at two educational institutions and a museum, in connection with a loan from Barclays Bank, PLC. Also made recommendations for an amount to be escrowed.

Interpreted chemical data at a Chelsea, Massachusetts, archeological site in terms of worker exposures and risks.

Calculated fugitive dust emissions from a salt storage pile, estimated downwind concentrations, and interpreted these in terms of potential materials damage for the City of Chelsea, Massachusetts.

Prior Experience

Brian L. Murphy Associates, 2002
 Sciences International, Vice President, 1999–2002
 IT Corporation (purchased Gradient), 1995–1999
 Gradient Corporation, President, 1985–1995
 ENSR (formerly ERT), 1975–1985
 Chief Scientist: Environmental Operations and Research
 Manager: Air Quality Studies Division

General Manager: Policy, Planning, and Earth Resources Center
Mount Auburn Research Associates, 1965–1975

Professional Affiliations

- Air and Waste Management Association
- International Society for Environmental Forensics
- American Chemical Society

Trial Testimony

Depositions

Charles W. Hoffman and Terry Susan Hoffmann v. Monsanto Company et al, US District Court for the Southern District of West Virginia, Civil Action No. 2:05-cv-00418, June 19, 2007.

Massachusetts Electric Company, et al. v. Travelers Casualty & Surety Company et al, Commonwealth of Massachusetts, Worcester Superior Court, December 9 and 10, 2004; May 12, 2005.

Consolidated Edison Company of New York, Inc. v. American Home Assurance Company et al., Supreme Court of the State of New York, County of New York, September 29–30 and December 14, 2004.

The United States of America v. Dravo Corporation et al. v. Bruckman Rubber and the City of Hastings, Nebraska, United States District Court for the District of Nebraska No. 8:01cv500, November 16, 2004.

Steven Woods et al. v. Trico Mechanical, Oxford County Superior Court, Docket Number CV-03-82, October 11, 2004.

Atlanta Gas Light v. UGI Utilities et al., United States District Court, Middle District of Florida Jacksonville Division, Case No. 3:03-CV-614-J-20 MMH, Case No. 01-600527, September 21, 2004.

Carol Antolovich, et al. v. Brown Group Retail, Incorporated, et al.; District Court, City and County of Denver, CO, January 25, 2001.

LILCO v Allianz Underwriters Insurance Company et al., Supreme Court of the State of New York, December 19 and 20, 2000.

James E. Barnett, Sr. et al. v. Monsanto Company et al, NO. 92-34865
80th Judicial District Court of Harris County, Texas, March 15, 2000.

Frank Theo Scott, Sr. et al. v. Thiokol Corporation et al. Civil Action No. 2:97-CV-151, US District Court for the Eastern District of Texas, Marshall Division, January 10, 2000.

In re: Tutu Wells CERCLA Litigation, District Court of the Virgin Islands, Division of St. Croix, Master Docket No. 1989-107-1227, October 22, 1999.

Janette L. Linck, et al. vs.. Enterprise Products Company, et al, District Court, Harris County, Texas, No. 97-27238, 334 Judicial District, October 1998.

Anita Michelle Allen, et al. v. Akzo Nobel Coatings, Inc., et al.; 60th Judicial District Court of Jefferson County Texas, October 24, 1996.

United States District Court for the Southern District of Alabama, Southern Division, Civil Action No. 92-0674-P-C, May 15 and 16, 1996.

Sierra Club vs. Public Service Company of Colorado, Inc, Salt River Project Agricultural Improvement and Power District and Pacificorp, Civil Action No. 93-B-1749, U.S. District Court for the District of Colorado, January 16, 1996.

Juan and Alma Alvear, et al. vs. Leonard Electric Products Company, et al, Cameron County, 107th Judicial District, June 27 and 28, 1995.

Brown et al. v. Centerline Circuits, Inc., et al. Boulder County District Court, Consolidated Civil Action No. 93-CV-223-2, October 19, 1994.

Aydin Corporation v. American Empire Insurance Company et al, Superior Court, County of San Francisco, No. 867826, April 8, 1993.

Consolidated Edison Company of New York, Inc. vs. Allians Insurance Company, Allstate Insurance Company, etc., et al, Superior Court of New Jersey, Docket No. BER-L-7519-91, September 8, 1992.

In re: Texas Eastern Transmission Corporation PCB Contamination Insurance Coverage Litigation, United States District Court for Eastern District of Pennsylvania, MDL Docket No. 764, May 31, 1991.

James Slaughter, et ux, Marilyn S. Slaughter et al vs. Farm and Home Savings Association. No. 86-42853, District Court of Harris County, Texas 151st District, June 2, July 6–7, 1989.

Remington Arms Company v. Liberty Mutual Insurance Company, United States District Court for the District of Delaware, C.A. No. 89-0420-JLL, September 12, 1989.

Anne Anderson et al. v. W.R. Grace & Co. et al, United States District Court, District of Massachusetts, Civil Action No. 82-1672-5, 1986.

United States of America et al. v. Hooker Chemicals and Plastics Corporation, United States District Court for the Western District of New York, Civil Action No. 79-989, Submitted Affidavit, December 13, 1985.

Trials and Arbitrations

Frank Theo Scott, Sr. et al. v. Thiokol Corporation et al. Civil Action No. 2:97-CV-151, US District Court for the Eastern District of Texas, Marshall Division, testimony at Daubert Hearing, February 10, 2000.

Brown et al. v. Centerline Circuits, Inc., et al. Boulder County District Court, Consolidated Civil Action No. 93-CV-223-2, October 19, 1994, testimony at trial May 10, 1995.

Aydin Corporation v. American Empire Insurance Company et al, Superior Court, County of San Francisco, No. 867826, testimony at Trial July 19, 1993.

Testified before an Administrative Law Judge regarding expansion of the Flying Cloud landfill in Eden Prairie, MN, Testimony at Hearing June 27 and 29, 1990.

James Slaughter, et ux, Marilyn S. Slaughter et al vs. Farm and Home Savings Association, No. 86-42853, District Court of Harris County, Texas 151st District, testimony at trial January 18, 1990.

Washington State Energy Facility Siting Commission, Application 76-2. Testified before an Administrative Law Judge regarding risks from explosions and oil spills due to development of the Northern Tier oil port in Puget Sound, 1981.

Attachment B

Materials Considered

January 27, 2009

Materials Considered

Apex Companies, LLC. 2008. Reports regarding SPR-LAL16-SP1. July 7, 2008

Apex Companies, LLC. 2008. Reports regarding SPR-LAL16-SP2. July 7, 2008

Camp Dresser and McKee. 2006. Soil and litter sampling program, Team 2-Book 1. July 18, 2006.

Cowan, C.D. 2008. Rebuttal report of Charles D. Cowan, Ph.D. Case No. 4:05-CV-00329-GFK-SAJ. In the U.S. District Court for the Northern District of Oklahoma.

Fiedler, H., C. Lau, L.O. Kjeller, and C. Rappe. 1996. Patterns and sources of polychlorinated dibenzo-p-dioxin and dibenzofuran found in soil and sediment samples in southern Mississippi. *Chemosphere* 32:421-432

Fisher, J.B. 2008. Expert report of J. Berton Fisher Ph.D., CPG, RPC. Case No. 4:05-CV-00329-GFK-SAJ. In the U.S. District Court for the Northern District of Oklahoma.

Johnson, G.W. 2008. Rebuttal report of Glenn W. Johnson, Ph.D., P.G. Case No. 4:05-CV-00329-GFK-SAJ. In the U.S. District Court for the Northern District of Oklahoma.

Mudge, S.M. 2007. Multivariate statistical methods in environmental forensics. *Environmental Forensics* 8:155-163

Olsen, R.L. 2007. Affidavit of Roger L. Olsen, Ph.D. October 26, 2007. Case No. 4:05-CV-00329-GFK-SAJ. In the U.S. District Court for the Northern District of Oklahoma.

Olsen, R.L. 2008. Expert report of Roger L. Olsen, Ph.D. Case No. 4:05-CV-00329-GFK-SAJ. In the U.S. District Court for the Northern District of Oklahoma.

Olsen, R.L. 2008. Deposition of Roger L. Olsen, Ph.D. taken September 10-11, 2008. Case No. 4:05-CV-00329-GFK-SAJ. In the U.S. District Court for the Northern District of Oklahoma.

Teaf, C.M. 2008. Expert report of Christopher M. Teaf, Ph.D. Case No. 4:05-CV-00329-GFK-SAJ. In the U.S. District Court for the Northern District of Oklahoma.

Wenning, R.J., D.J. Paustenbach, M.A. Harris, and H. Bedbury. 1993. Principal components analysis of potential sources of polychlorinated dibenzo-p-dioxin and dibenzofuran residues in surficial sediments from Newark Bay, New Jersey. *Arch. Environ. Contam. Toxicol.* 24:271-289

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